UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1492

Washington, D. C. ▼ February, 1928

SOME RESULTS OF SOFT-PORK INVESTIGATIONS, II

Conducted jointly by the

UNITED STATES DEPARTMENT OF AGRICULTURE

and the

AGRICULTURAL EXPERIMENT STATIONS

of

ARKANSAS
GEORGIA
INDIANA
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STATEMENT OF AUTHORSHIP

This is the second bulletin published jointly by the department and several State experiment stations to report results of cooperative soft-pork investigations. The first publication, Department Bulletin 1407, entitled "Some Results of Soft-Pork Investigations," was issued in April, 1926. The reader is referred to the introductory pages of that bulletin for a detailed presentation and discussion of the various aspects and phases of the soft-pork problem and of the methods employed in the cooperative study. In this bulletin only sufficient explanation relating to the problem and methods is given to furnish a background for the reader who has not read Department Bulletin 1407. While the investigations are being continued it is the purpose to present in detail the data and conclusions which have been agreed on for issuance by the cooperating institutions since the first bulletin was completed. The results reported were obtained under the direction of the following:

E. Z. Russell, Bureau of Animal Industry.
O. G. Hankins, Bureau of Animal Industry.
N. R. Ellis, Bureau of Animal Industry.
J. H. Zeller, Bureau of Animal Industry.
Edgar Martin, Arkansas Agricultural Experiment Station.
S. W. Greene, Coastal Plain Experiment Station.
D. G. Sullins,[1] Georgia Agricultural Experiment Station.
F. H. Smith,[1] Georgia Agricultural Experiment Station.
J. R. Quesenberry,[2] Iberia Livestock Experiment Farm.
C. M. Vestal, Indiana (Purdue University) Agricultural Experiment Station.
G. S. Templeton, Mississippi Agricultural Experiment Station.
C. J. Goodell,[1] Mississippi Agricultural Experiment Station.
E. H. Hostetler, North Carolina Agricultural Experiment Station.
A. L. DuRant, South Carolina Agricultural Experiment Station.
E. G. Godbey, South Carolina Agricultural Experiment Station.
W. D. Salmon,[1] South Carolina Agricultural Experiment Station.

Credit is due L. W. Himmler,[1] H. S. Isbell,[1] and S. J. Dahl,[1] of the Bureau of Animal Industry, for assistance in the laboratory work, and to K. F. Warner, of the Bureau of Animal Industry, for supervision of the slaughtering at the United States Animal Husbandry Experiment Farm, Beltsville, Md.

By cooperative agreement the results of the investigations are shared jointly and equally by participating institutions. Each cooperating State is authorized also to publish this report in full or in part as a State bulletin with supplementary data, if desired, relative to the local phases of the soft-pork problem, giving due credit to this publication.

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[1] Resigned.
[2] Transferred to department station at Miles City, Mont.

UNITED STATES DEPARTMENT OF AGRICULTURE

In Cooperation with the
Agricultural Experiment Stations of Arkansas, Georgia, Indiana, Mississippi, North Carolina, and South Carolina

DEPARTMENT BULLETIN No. 1492

Washington, D. C. ▼ February, 1928

SOME RESULTS OF SOFT-PORK INVESTIGATIONS, II

Prepared by O. G. HANKINS, *Animal Husbandman;* N. R. ELLIS, *Associate Biological Chemist;* and J. H. ZELLER, *Assistant Animal Husbandman, Animal Husbandry Division, Bureau of Animal Industry,* in consultation with those named on the preceding page as responsible for the work

CONTENTS

THE SOFT-PORK PROBLEM

The products of soft hogs have certain undesirable characteristics. There is a lack of firmness in the fat which may be so extreme as to cause a typical soft, flaccid, shapeless condition in the products, which makes them inconvenient to handle and unattractive to many people. The hams are probably least and the lard most subject to criticism, depending on the proportion of fat in the product.

The soft-pork problem until recent years was considered as sectional in scope, important only in peanut-producing localities. Establishment of the fact that other feeds, especially soy beans, have a softening influence on hogs has expanded the problem to one of nation-wide importance. Soy beans have a wider adaptation, are produced in greater quantity, and are utilized in pork production to a greater extent than any other recognized softening feed.

Producers, packers, dealers, and consumers are concerned in the problem of soft pork. The producer marketing medium soft, soft, or

oily[1] hogs from sections of the country known as soft-hog territories must accept a lower price in the usual case than if the hogs are firm. This price difference varies considerably, and no reliable average figure is available, but it is estimated at about 2 cents a pound on the live-weight basis. This represents a very large sum when considered collectively for the country as a unit and for any considerable period of time. The packer meets with various difficulties in handling soft hogs in the packing house and in sending the products along the channels of trade. (Fig. 1.) This explains the lower price which he pays for such hogs. The retail dealer prefers to handle products from firm hogs and can sell them to his customers with greater mutual satisfaction. Such products hold their shape better, cut better, and present a more attractive appearance than those from soft hogs. (Figs. 2 and 3.)

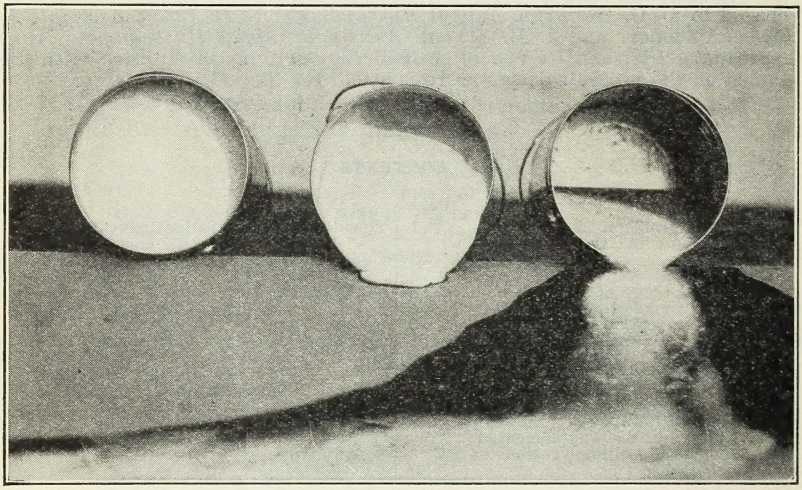

FIG. 1.—Lard from hard, soft, and oily carcasses

COOPERATION IN THE INVESTIGATIONS

On July 1, 1919, the Bureau of Animal Industry, United States Department of Agriculture, with cooperating agencies, undertook a comprehensive investigation of the soft-pork problem. It was generally conceded that the independent work which had been done in a disconnected way by various institutions had not resulted in satisfactory progress toward solution of the problem in the United States. Combined effort by the department and the State experiment stations was regarded as promising better progress and quicker solution. Thus the investigation was begun on that basis and has been so conducted without interruption. The Institute of American Meat Packers has assisted in the work throughout by furnishing a repre-

[1] The physical grades recognized in these investigations (given in decreasing order of firmness) are: (1) Hard, (2) medium hard, (3) medium soft, (4) soft, and (5) oily.

sentative on the carcass-grading committee.[2] This committee graded for firmness the carcasses of the hogs used in connection with these studies.

The hogs were fed by the various institutions cooperating in the work according to the plans of the experiments agreed to by the group of cooperators, and were shipped to the United States Animal Husbandry Experiment Farm for slaughter, grading, and laboratory study of the fats. This centralization of slaughtering has been accompanied by a standardization of methods in the measurement of results which is regarded as very valuable. It is considered as an important improvement over the independent work done previously, in which the slaughtering was carried out at various commercial packing

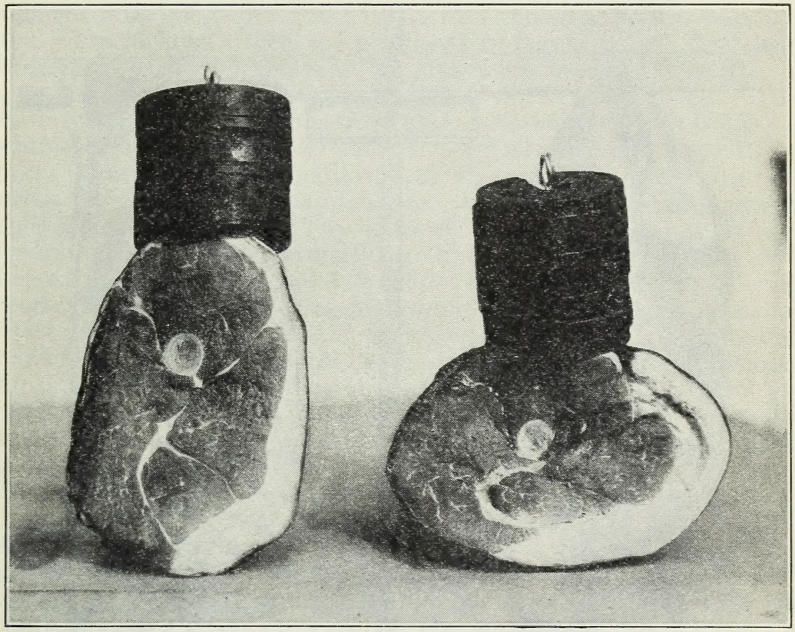

FIG. 2.—Smoked hams from hard and soft carcasses. Each ham supports a weight of 6.5 pounds

plants, the carcass grading by different committees with varying standards of firmness, and the laboratory work in different laboratories by various chemists using dissimilar tests in many cases. In the present investigations the refractive index has been adopted as the standard laboratory measure of firmness of the fats. It is as reliable as any of the other tests and can be determined with greater rapidity.

[2] The carcass-grading committee is composed of a representative of the Institute of American Meat Packers, a representative of the State experiment stations, and a representative of the Bureau of Animal Industry. Howard R. Smith, Baltimore, Md., until recently represented the meat packers and Earl H. Hostetler, of the North Carolina Agricultural Experiment Station, the State experiment stations, on the grading committee continuously from the beginning of the cooperative work. G. T. Cole, in charge of Federal meat-inspection work at Moultrie, Ga., represented the bureau during the first year, and H. K. Walter, who occupies a corresponding position at Washington, D. C., during the succeeding years. Anton A. Auth, Washington, D. C., recently succeeded Mr. Smith.

At the close of each year's work a conference of representatives of the institutions cooperating in the investigations was held. The complete results of the experiments were presented and analyzed. Such conclusions as seemed justified were drafted and approved by the conference to be made public. When sufficient authentic data and conclusions had been accumulated the conference recommended the publication of a bulletin. The present bulletin is the second so recommended in connection with these cooperative soft-pork investigations. As a final step the annual conference, having at hand complete information as to the status of each phase of the work, formulated a program of experiments for the following year. The various

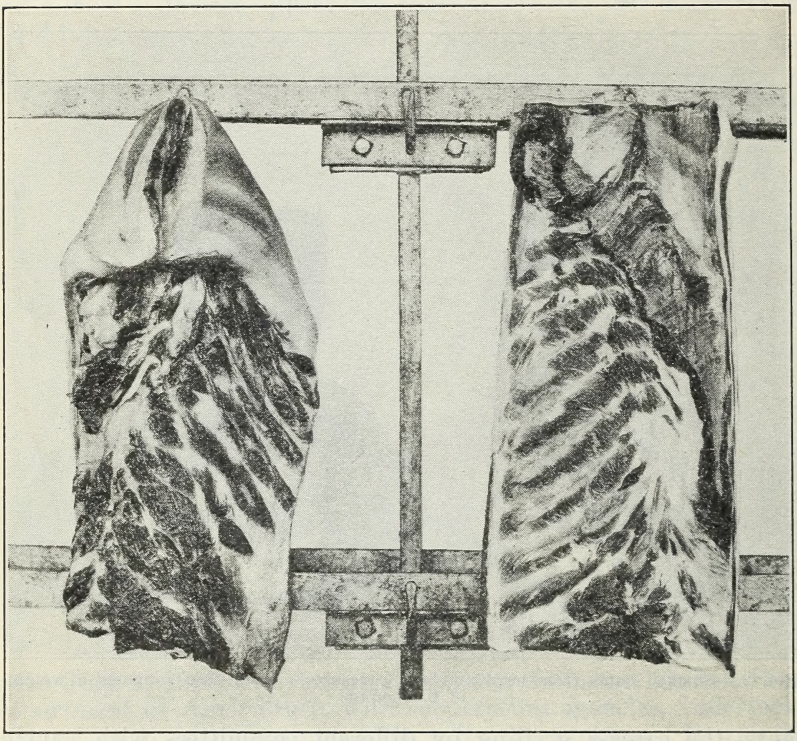

FIG. 3.—Fresh bacon from oily and hard carcasses

stations then planned their work for the year to conform to this program.

FUNDAMENTALS OF THE PROBLEM

It has been indicated that softness of the fat is responsible for softness in hog carcasses and products. Conversely, when the fat of a carcass is firm the carcass and products are firm. The soft-pork problem is fundamentally, therefore, a fat problem. Study of body fat and of the constituents which enter into its production is a basic requirement of these investigations.

The quantity and quality of the fat in feeds exert a wide range of influence on the firmness of body fat. It is well known that when the fat of feeds is stored by the hog there is no essential change in

its character so far as firmness or softness is concerned. It is an interesting fact that the fat of most of the common feeds is soft and in some cases oily or fluid at ordinary temperatures. The percentage of fat in the more or less common hog feeds varies widely, from less than 1 per cent to approximately 50 per cent.[3] With some of the high-fat feeds the hog consumes fat enough to account for all of that stored, and in these cases the body fat bears remarkable resemblance to the fat of the feed. On the other hand, with feeds containing a low percentage of soft or oily fat, the body fat produced shows little similarity to the fat of the feed. In the latter case the body fat, as a rule, is decidedly firm when the hog has been fed to a reasonable degree of finish.

With the fat of most of the common feeds exerting a softening influence the question arises: What feed constituents are responsible for the firm hogs which are produced in many cases? The animal body uses carbohydrates first to supply its need for energy. Any surplus above this need goes to build up a store of fat. Under the usual conditions of hog feeding in this country this is the chief source of synthesized body fat. Protein also may be used to form body fat under certain conditions, as when fed in excess of the body's needs for growth and maintenance. Under usual feeding practices this seldom happens. There is much evidence to show that carbohydrates and protein normally produce firm fat in the body of the hog and no evidence to indicate that they produce soft fat. Common feeds and feed combinations containing high percentages of carbohydrates and low percentages of fat are now recognized as producers of hard hogs, when the animals are fed to at least a moderate degree of finish. To summarize: The character of fat stored seems to a great extent to be governed, primarily, by the amount and character of fat, and, secondarily, by the amounts of the other nutrients, particularly the carbohydrates, in the feed consumed in relation to the rate of fat deposition.

In the normal process of growing and fattening, the rate of fat deposition in a hog gradually increases. While the 50-pound pig stores fat at a low rate, the percentage of fat in the gain of a 150-pound animal is relatively high. This is a significant fact when considered in connection with the character of fat stored from any certain feed or feed combination, particularly one moderately low in fat. Such a feed may contain practically enough fat to satisfy the fat-storage requirements of the younger animal, resulting in the deposition of a soft body fat. With the increasing rate of storage as the animal matures, however, there is a corresponding decrease in the feed fat available for deposition. Under these conditions the other nutrients, usually the carbohydrates, must furnish an increasing supply of material for transformation into body fat. Thus a hog fed to maturity on a ration moderately low in softening fat gradually becomes firmer as it acquires weight and finish.

BROADENED SCOPE OF THE WORK

At the beginning of these investigations the peanut was the feed which stood forth, demanding the first consideration. In consequence most of the early experiments were planned to study the

[3] See Department Bulletin 1407 (*p. 13, Table 2*) for fat composition of common hog feeds.

effects of that feed on firmness under various conditions, and to determine the requirements for hardening peanut-fed hogs on different hardening feeds. While work along these lines has been continued, it was soon found necessary to investigate other feeds, as well as factors aside from feed. Among the other feeds which called for study on account of their probable softening influence were rice polish, rice bran, mast, and soy beans. The other factors which early showed their possible influence were initial weight, rate of gain, finish, sex, thrift, previous treatment, and breed. Thus the scope of the work was greatly broadened. Certain conclusions have been reached and published with the data supporting them. Specific reference will be made to those results at appropriate points in this bulletin.

RELATION OF COMPOSITION OF FAT TO FIRMNESS OF CARCASS

The firmness of the carcass is in large measure determined by the firmness of the adipose tissues and this in turn by the composition of the fat contained in these tissues. Analyses of the fat have shown that increasing unsaturation of the fat is accompanied by increasing softness of the carcass. It has therefore seemed desirable to determine the relationship between the committee grades and the composition of the fat. From this information one may be interpreted in terms of the other, and the data from both sources taken together give added exactness to the experimental results.

Both methods of evaluating firmness have proved their usefulness throughout the investigations. The physical grading of the carcass, according to recognized commercial standards, is a very practical means of classification from the marketing standpoint. The data on the composition of the fat when in terms of such fat constants as the iodine number or refractive index give a general but reliable knowledge of the composition, while the more detailed and more difficult analysis for the content of the several fatty acids gives a deeper insight into the fundamental character of the effects of feeds and other factors on fat formation. This section of the bulletin is concerned principally with the comparison of refractive index and iodine values to the committee grades and is based on the results of those experiments which have been summarized in Department Bulletin 1407 (*4*)[4] as well as in this bulletin.

As would be expected in a study of this sort, where two such widely different methods are used, there have been numerous divergent results between laboratory tests and committee gradings. In some cases the laboratory test has failed to indicate the degree of softness; in others the committee grading has been at fault. Numerous factors affect the results, many of which are not well understood. The data on refractive index as well as iodine numbers have been summarized according to feeds and feed combinations, since it was found that standards of firmness as determined by laboratory tests varied with the rations fed. These variations have been ascribed largely to the variations in the amount and the degree of unsaturation of the feed fat.

Soft lard ordinarily contains a greater amount of unsaturated, or liquid, fatty acids than hard lard. However, the proportions as well

[4] Italic numbers in parentheses refer to "Literature cited," p. 50.

as the total amount of the predominating unsaturated acids (oleic and linolic) may vary according to the rations employed. The same situation may prevail in the case of the saturated acids (stearic and palmitic) although recent data (*3*) show approximately twice as much palmitic acid as stearic acid. The results of fatty-acid analyses (*2*) have shown that the body fats from hogs fed different feeds vary widely in their fatty-acid composition. Lards from hogs fed on soy beans have been found to contain nearly equal quantities of oleic and linolic acids, while lards from hogs fed brewers' rice as the basal feed contained a relatively high amount of oleic acid and very little linolic acid. Lards of apparently equal firmness have been found to have differing proportions of fatty acids. Although little is known of the nature of the glycerides, it is evident that those formed during the feeding of a softening ration followed by a hardening ration may be materially different from those formed during the simultaneous feeding of softening and hardening feeds.

It has been stated (*4*) that comparison of the various fat constants during the present investigations has shown that the melting point was less reliable than the refractive index or iodine number as a measure of firmness. Of the two latter methods, the refractive index has been adopted as the routine test. Under the uniform conditions prevailing in the handling of the fat samples and in making the refractive-index readings this test has shown a slightly higher correlation with committee grades and has been more useful because of the rapidity of determination as compared to the iodine number. The readings on preliminary fat samples which are available for comparison at the time the carcasses are graded have been particularly valuable. The refraction of unsaturated acids is known to be higher than that of saturated acids. This probably largely explains the parallelism of iodine and refraction values as associated with lard and renders the determination of both values unnecessary in the majority of cases.

Inability to explain certain cases of marked irregularities between grades and refractive indexes was noted early in the work. It was also apparent that there were conditions under which a single scale of grade limits was not entirely applicable. The following statement was accordingly made in Department Bulletin 1407 (*4, p. 11*):

> The refractive index does not always give an exact measure of the firmness of the hog carcass. In some cases the discrepancy in the refractive index as indicated by the committee grading is due to the nature of the adipose tissue, particularly its thickness and fat content; in other cases it appears to be due to the specific effect on the fat of a certain kind of feeding. However, the refractive index not only gives a check on the gradings but it furnishes a satisfactory means of comparing and showing slight changes in the degree of firmness which are not shown well by the gradings alone.

Further study of the subject has accordingly been made from available data on fat constants as well as on fatty-acid separations. Grade limits for refractive-index and iodine-number values have been determined wherever possible to cover the lines of experimental feeding thus far reported. Particular attention has been given to the results on the back fat, since it has been found to be representative of the entire body fat. The difference between leaf fat and back fat varies somewhat with the ration used. Leaf fat is occasionally as soft as the back fat. The tabulation of refractive-index values according to

grades has been made for all the hogs within each of the main experimental feeding plans included in the study. In the case of the iodine number complete records were not available, but recent determinations on additional samples have furnished sufficient data to establish grade limits in a large number of cases. The marking off of grade limits is often difficult, owing to the low correlation of gradings and fat constants. The limits as here given do indicate the maximum number of hogs possible to include within the indicated limits for the data at hand. Those groups showing similar limits are classed together.

Reference to the lists of feeds and feed combinations given in Table 1 shows that a large number of these (ration Group A) were grouped together for the general refractive-index grade limits, as previously stated (*4*). Fats which have been formed on rations containing the basal feeds, corn, brewers' rice, peanuts, soy beans, peanut meal with corn, and also corn following soy beans alone or supplemented with a medium ration of corn, show similar correlation of refractive-index and iodine values to committee grades. This list covers a range from the hardest to the softest fats which have been observed in soft-pork experiments. Studies on the fatty-acid composition of fats produced on the feeds just mentioned have shown (*3*) a pronounced rise in linolic acid and a drop in saturated acids, with increasing softness. In fact, the change in iodine number and refractive index is reflected very closely in the change in the linolic acid. Soy-bean feeding has caused a more abrupt rise in linolic acid, accompanied by a drop in oleic acid, than with peanut feeding, although the degree of softness was similar. An approximate ratio of one part stearic to two parts palmitic acid was found in fats from hogs fed corn, brewer's rice, peanuts, and soy beans. The total amount of saturated acids, however, appears to be an excellent criterion of firmness and to explain numerous cases in which the fat constants and the percentage of linolic acid are at variance with the grading on the carcass. Certain examples of this will be mentioned later.

TABLE 1.—*Refractive index and iodine number limits for grades of carcasses*

	Ration Group A	Ration Group B	Ration Group C	Ration Group D
Item	1. Corn and supplements. 2. Brewers' rice and supplements. 3. Peanuts. 4. Soy beans. 5. Corn following (4). 6. Soy beans and medium ration of corn. 7. Corn following (6). 8. Peanut meal with corn.	1. Rice polish and tankage. 2. Rice bran and tankage. 3. Corn or brewers' rice following both (1) and (2).	1. Corn following peanuts to pigs of initial weight of 85 pounds or over.	1. Pigs of slaughter weight under 125 pounds.
	REFRACTIVE INDEX			
Number of hogs	1,025	299	139	400.
Carcass grade:				
Hard	1.4597 and below	1.4592 and below	1.4596 and below	1.4594 and below.
Medium hard	1.4598 to 1.4601	1.4593 to 1.4596	1.4597 to 1.4598	1.4595 to 1.4598.
Medium soft	1.45602 to 1.4605	1.4597 to 1.4600	1.4599 to 1.4600	1.4599 to 1.4601.
Soft	1.4606 to 1.4618	1.4601 and above	1.4601 to 1.4614	1.4602 to 1.4619.
Oily	1.4619 and above	Occasional oily		1.4620 and above.

TABLE 1.—*Refractive index and iodine number limits for grades of carcasses*—Continued

IODINE NUMBER

	Ration Group A	Ration Group B	Ration Group C	Ration Group D
Number of hogs	465	216	139	
Carcass grade:				
Hard	66.4 and under	60.9 and under	Limits ill defined for all grades. Soft hogs run from 69 to 78.	Limits not determined.
Medium hard	67 to 70.4	61 to 64.9		
Medium soft	70.5 to 72.9	65 to 68.9		
Soft	73 to 83.4	69 and above		
Oily	83.5 and above	Occasional oily		

Except for the cases in which corn followed a softening period on soy beans alone or supplemented with corn, the rations listed in Group A were fed throughout the experimental period.

The rations listed under Group B represent the feeding of rice polish and rice bran and these feeds followed by corn and brewers' rice. The grade limits of both the fat constants are decidedly lower throughout than those of the previous group. The low limits for hard and medium-hard hogs are especially noteworthy. Thus, for a refractive index of 1.4595, hogs fed rice bran or polish and hardened on corn or brewers' rice were graded medium hard, while if fattened on corn throughout they were graded strictly hard. This discrepancy must necessarily lie in a difference in the composition or structure of the fat which is not shown in the fat constants. Unpublished data on the fatty-acid composition of lards from hogs fed the various combinations of rice by-products and corn show the usual fluctuation of linolic acid with refractive index and iodine number. The saturated-acid content appears to be the better criterion of firmness although changes in the ratio of linolic acid may modify this relationship in some cases. As applied to the case cited for fats of the same refractive index but of different grades, the medium-hard hogs fed rice bran or rice polish showed a lower saturated-acid content in the lard than the hard hogs raised on corn.

The combination of peanuts followed by corn (Ration Group C) necessitated a different scale. In the latter case the large quantity of unsaturated glycerides formed during the feeding of peanuts had caused the retention of the soft condition beyond the usual points indicated by fat constants according to the scale of Ration Group A. In addition, the saturated-acid content of these peanut-corn lards tends to be comparatively low. Most of the 139 hogs included in this group were graded soft. The most striking point of the refractive-index grade limits is the very narrow range of the two medium grades. Possibly greater numbers of hard and medium-hard hogs would change the dividing point for these grades. From this situation it would appear to be rather difficult at times to determine satisfactorily the physical grade of the carcass, particularly those of moderate firmness. The limits of grades for iodine numbers in this group were so ill defined that it was concluded that this constant was of little value. In the case of the Group A rations, the iodine number was as reliable as the refractive index. In other words, the percentages of values for the two constants which were within the respective grade limits were very close, namely about 75 per cent.

The last column (Ration Group D) in Table 1 relates to pigs slaughtered at weights under 125 pounds, and figures for the refractive index only are given. Sufficient data on iodine numbers were not available to determine the limits, but so far as noted the values parallel those of the refractive index. The limits of grades for the refractive index are in most cases 2 points higher than in Ration Group B and about 3 points lower than in Ration Group A. Explanation of this behavior appears to center in the adipose tissue rather than in the fat itself. Young pigs usually have a relatively thin layer of adipose tissue which has not become filled with fat. The composition of the adipose tissue has been found to vary with the fatness and size of the animal. The protein and water content decrease while the fat content increases as the animal takes on weight and finish.

The smaller quantity of fat in the adipose tissue with consequent higher quantity of protein tissue of the lightweight and thin pigs appears to result in a measurable masking of the real firmness or softness of the fat. The low relative thickness of the adipose tissue acts in a similar manner. In many instances there are wide variations in the fatness of animals of the same weight within the 125-pound limit. On a corn ration the fat pigs of 100 pounds are usually more comparable, from the grading standpoint, to animals weighing considerably more than 125 pounds. This, in part, is explained by the greater firmness of the body fat as shown by the refractive index and also by the character of the adipose tissue.

It appears, from an examination of the data on a large number of lightweight "check" pigs, that, from the market standpoint, the carcass grading is a safe criterion of the condition of the carcass. However, greater emphasis must be placed on the actual composition of the fat in studying the changes produced by feeds and other factors on the body fat. There have been numerous instances in which variations in the feed before the experimental period, which were particularly reflected in the refractive index and not in the gradings, have had a marked influence on the final results of the experimental feeding.

In addition to the determining of grade limits, further comparison has been made of the parallelism between the refractive index and the iodine number as they measure increasing softness or hardness. Group averages of iodine numbers have been made which are comparable, so far as a smaller number of determinations permit, with the refractive-index averages used in preparing the various graphs of this bulletin and of Department Bulletin 1407(4). From comparison of the data on the same samples, corresponding values for the two constants were determined and a complete scale of the iodine number which paralleled the refractive index was constructed. The results from the rations listed in Group A of Table 1 were used for the most part in constructing this parallel scale, shown in Figure 4.

The refractive index is given at the left and iodine number at the right as abscissas. The weights of the hogs are charted as ordinates to show progressive changes in the two values.

The results shown in Figure 4 confirm the statement that the iodine and refractive-index values are usually in close agreement. The rations listed in Group A of Table 1 have furnished values showing a

very close parallelism. In the case of rice polish and tankage, the refractive-index values run relatively low. It will be recalled that the grade limits for rice-bran and rice-polish feeding are lower than in most of the rations. This behavior indicates that factors other than the degree of unsaturation as indicated by the iodine number influence the refractive index and the firmness of the adipose tissue. The feeding of corn following peanuts to pigs of 100 pounds' initial weight causes a more rapid decline in the refractive index than in the iodine number. Since there is a general lack of agreement between iodine numbers and gradings, in the case of this combination

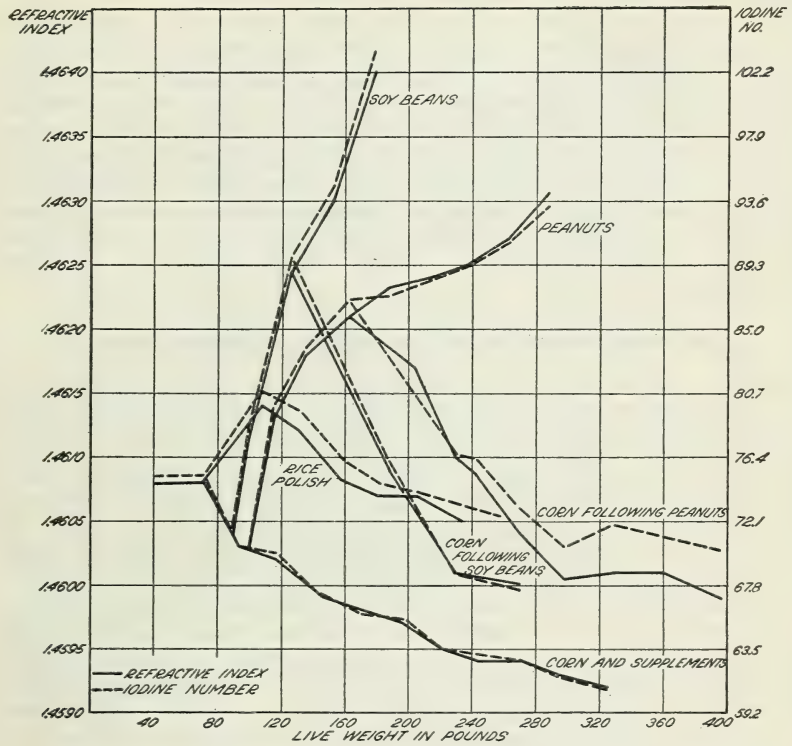

FIG. 4.—Comparison of refractive-index and iodine-number values with respect to the firmness of the fat formed on different rations

of feeds the failure of the two fat constants to follow a parallel course such as the other rations show may not have much significance.

RESULTS OF THE INVESTIGATIONS

CLASSES OF PIGS USED

Initial weight has been recognized in these investigations as a factor of importance enough to require control in connection with the various experiments. Therefore, in the plans of the experiments initial-weight limitations have been specified. Conditions have made it impossible to adhere strictly to these in all cases, but they have been followed without deviation in groupings and study of

data from animals used in the different experiments. Specific reference will be made to initial weight under each of the sections reporting conclusive results, which are to follow.

To avoid the use of unthrifty animals it was agreed by the cooperating agencies early in the investigations that pigs having an initial weight of approximately 100 pounds should be not more than six or seven months of age, with those of higher or lower weights varying in maximum age accordingly. The degree of leniency suggested by this standard seemed necessary on account of the difficulties often experienced by some stations in obtaining suitable experimental animals.

To a very considerable extent the pigs used in the experiments were well bred. Most of them were purebreds, the Berkshire, Chester-White, Duroc-Jersey, Hampshire, Poland-China, and Tamworth breeds being represented. In addition, there were a number of grades and crossbreds, and some of mixed or unknown breeding. Effort was made in all cases to balance the sex factor by using equal numbers of barrows and sows. Type is a factor recognized as probably influencing variations in firmness, and, therefore, in these experiments uniformity in type among the pigs was sought and attained to a very great extent. With few exceptions the pigs used were of medium type.

A. CORN WITH NONSOFTENING SUPPLEMENTS FOLLOWING PEANUTS

Results from feeding corn with nonsoftening protein supplements for hardening purposes following peanuts were reported in detail in Department Bulletin 1407 (*4*). The results given were confined to those obtained from pigs weighing from 85 to 114 pounds, inclusive, when the peanut feeding was begun. Data from 97 animals were presented and discussed, and certain conclusions stated. It was pointed out that peanuts are decidedly softening and that corn with nonsoftening protein supplements fed after peanuts has a hardening influence, although the hardening progresses rather slowly. It was impossible to recommend a practical method of producing strictly hard carcasses with pigs having the range of initial weights given above, when they have been fed peanuts for a period of about eight weeks. Excessive gains on the hardening ration, far beyond the practical point, had been required to produce even medium-hard carcasses.

Further work along this line has furnished data from 15 additional hogs, fed at the Animal Husbandry Experiment Farm, which have been studied in conjunction with the 97 previously considered. The added data have given no essentially different aspect to the question. It is possible now, however, to state more definitely the results which may be expected from this plan of feeding. The following conclusion relating to this question was released after the 1925 conference of the cooperating agencies (*7*).

Peanuts grazed or self-fed in dry lot with or without minerals to pigs starting at weights ranging from 85 to 115 pounds and making gains of approximately 40 pounds or more on that feed through a period of approximately eight weeks will not produce firm carcasses at the usual market weight of 200 to 225 pounds attained by subsequent feeding of corn with tankage after the peanuts.

Results have shown, in fact, that gain on corn with tankage up to approximately 120 pounds, this maximum being produced during a feeding period of approximately 16 weeks' duration, following gains of 40 or more pounds on peanuts, usually will not produce hard or medium-hard hogs. As the gain on peanuts increases the subsequent gain on corn with tankage necessary to produce a certain degree of firmness likewise increases.

The apparent deduction to be drawn from this conclusion is that although it is possible to produce medium-hard or hard hogs with this plan of feeding, it is probably quite impractical to attempt it under the ordinary economic conditions.

RESULTS FROM HEAVIER PIGS

With the realization that initial weight is a factor of importance in producing variations in firmness, a study was made of results from hogs fed peanuts followed by corn with nonsoftening protein supplements, beginning at weights above 114 pounds. Data from 27 hogs fed in one experiment each at the Georgia and South Carolina stations and in four experiments at the Animal Husbandry Experiment Farm were included in this study. The peanut-feeding period in all cases was about 8 weeks, while the hardening period varied from 4 to 24 weeks.

With the exceptions of two hogs which were fed wheat middlings and one fed cottonseed meal as a replacement for tankage during the final 3-week period of an experiment, all the hogs received tankage as the supplement to corn in the hardening ration. No noteworthy differences in firmness could be detected under the conditions of the experiments, and the results from the three hogs were summarized with those from the hogs fed tankage. The tankage in all cases and the wheat middlings to the two hogs reported were self-fed, free choice, with the corn. The cottonseed meal fed during the 3-week period in the one instance comprised one-third of a mixture with ground corn, the mixture being self-fed.

Table 2 gives a summary of results from the 27 hogs included in this study.

TABLE 2.—*Average weights, gains, days on feed, gradings, and refractive indexes of back and leaf fats for 27 hogs fed peanuts followed by corn with nonsoftening supplments*

[Range of initial weights on peanuts, 115 to 142 pounds]

Number of hogs	Initial weight	Gain		Days on feed		Final weight	Slaughter weight	Grading	Refractive index	
		Peanuts	Corn	Peanuts	Corn				Back fat	Leaf fat
	Pounds	*Pounds*	*Pounds*			*Pounds*	*Pounds*			
27	124.04	54.78	136.04	55.63	106.52	314.86	307.37	Medium soft	1.4603	1.4599

It is especially noteworthy that the pigs were heavy as feeders at the beginning of the peanut feeding, the range of initial weights being from 115 to 142 pounds, and the average initial weight about 124 pounds. The average weight at the close of the peanut-feeding period was 178.82 pounds, which is a very good market weight in many sections of the country. In the study of hardening require-

ments, however, an additional increase in weight, averaging 136.04 pounds, was made on the hardening ration. This was 2.48 times the gain previously made on peanuts. Despite this large gain on the hardening feed, resulting in excessive finished weight, the average committee grading was medium soft, with a corresponding refractive index of 1.4603.

Figure 5 shows in graphic form the results from this group of hogs.

The 27 hogs having a range of initial weights from 115 to 142 pounds, inclusive, were divided into two major groups according to the gains made on peanuts, as follows: Group 1, 25 to 49 pounds, and Group 2, 50 to 74 pounds. The hogs in each group were then sub-

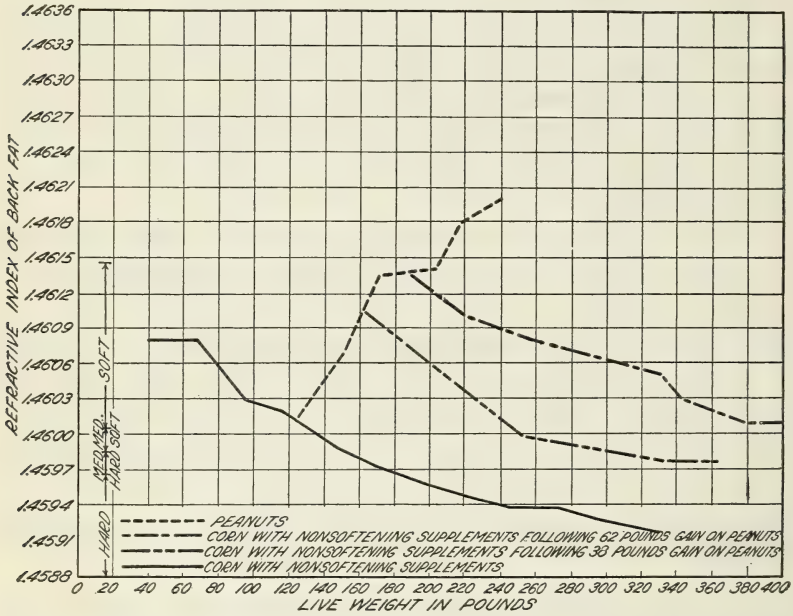

FIG. 5.—Hardening on corn with nonsoftening supplements following softening on peanuts. Initial weights of pigs, 115 to 142 pounds. Grade limits of refractive index which are shown apply only to the two curves which represent hardening. Those for softening on peanuts and for progressive hardening on corn with nonsoftening supplements are shown in Table 1

grouped in 25-pound intervals, according to gains made on the hardening ration. Averages of the data by subgroups were determined for charting purposes. The curves for the progressive hardening on corn with nonsoftening supplements and for the softening on peanuts are the same as shown in Department Bulletin 1407 (*4*, *fig. 10*). Points on the latter curve representing 38 pounds' gain and 62 pounds' gain on peanuts (the averages for the two major groups) were taken as starting points for the two curves representing hardening on corn after softening on peanuts.

The influence of the difference in gain on peanuts is strikingly shown. At their closest approach the two curves which represent hardening are apart nearly 3.5 points in refractive index. The very slow hardening which occurred in both groups is, likewise, very

clearly illustrated. It is apparent that the hardening progressed much more slowly than the softening which preceded it. This seems true particularly of the group which made an average gain of 62 pounds on peanuts. The curve for the group which made an average gain of 38 pounds on peanuts may be somewhat misleading, however, as it is based on data from a smaller number of animals than the other. It is probable that with a larger number of hogs the curve would more nearly parallel the other. Neither of the curves makes a close approach to the base curve which represents the increasing firmness of hogs grown and fattened exclusively on corn with non-softening supplements. At the nearest point there is a difference of 5.5 points in refractive index.

It is apparent in comparing these results with those obtained from pigs having initial weights of from 85 to 114 pounds, inclusive, that it is fully as difficult to produce firm hogs from the heavier pigs as from the lighter. In fact, there is an indication that the hardening progresses more slowly in the heavier pigs, the gains on peanuts having been equal. Obviously, the deduction must be made that it is as impracticable, or probably more so, under the ordinary economic conditions, to attempt to produce hard or medium-hard hogs from the heavier pigs as from 85 to 114 pound pigs, when this plan of feeding is used. These results strongly suggest that if a practical plan of producing firm hogs under this system of feeding is to be developed it must make use of pigs weighing less than 85 pounds at the beginning of the peanut feeding.

FEEDING RESULTS WITH CORN AND TANKAGE FOLLOWING PEANUTS

Feeding results are available from one experiment in which corn was fed with tankage following peanuts to pigs having an average initial weight over 114 pounds. The pigs were fed at the Animal Husbandry Experiment Farm during the years 1924–25.

The peanuts used in this experiment were low grade, shelled, or of the grade known commercially as "pickouts" or "shelling stock." The composition is shown in Table 3.

TABLE 3.—*Composition of shelled peanuts*

Water	Ash	Crude protein	Fiber	Nitrogen-free extract	Fat
Per cent 4.9	*Per cent* 5.7	*Per cent* 26.3	*Per cent* 2.5	*Per cent* 24.3	*Per cent* 36.3

The peanuts were self-fed, free choice, with mineral mixture [5] for 56 days, when a hardening period of 24 weeks' duration was begun. Shelled corn, tankage, and mineral mixture, self-fed, free choice, were used for the hardening purposes. Killings of 10, 9, and 10 hogs were made after 16, 20, and 24 weeks' hardening, respectively, but in reporting results in Table 4 only a general average of data for all the

[5] Mineral mixture composed as follows: Charcoal, 75 pounds (3 bushels); raw phosphate rock, 3 pounds; common salt, 6 pounds; Glauber salt, 6 pounds; ground limestone, 6 pounds; flowers of sulphur, 3 pounds; and copperas (pulverized sulphate of iron), 1 pound.

hogs is given. Essential data pertaining to both the peanut-feeding period and the hardening period are given in Table 4.

TABLE 4.—*Results of feeding corn and tankage self-fed, free choice, in dry lot following peanuts self-fed in dry lot*

PEANUT-FEEDING PERIOD		
Number of pigs used		30
Average number of days fed		56
Average initial weight	pounds	116.16
Average final weight	do	164.13
Average gain	do	47.97
Average daily gain	do	.86
Feed consumed per 100 pounds gain:		
Shelled peanuts	do	310.98
Mineral mixture	do	10.77
Total feed	do	321.75
CORN-AND-TANKAGE-FEEDING PERIOD		
Number of pigs used		30
Average number of days fed		134.77
Average initial weight	pounds	164.13
Average final weight	do	347.60
Average gain	do	183.47
Average daily gain	do	1.36
Feed consumed per 100 pounds gain:		
Shelled corn	do	457.03
Tankage	do	19.99
Mineral mixture	do	6.09
Total feed	do	483.11

The rate of gain during the peanut-feeding period was below normal, while the quantity of feed consumed per 100 pounds gain was somewhat high. The rather low quality of the peanuts fed probably accounts for the subnormal showing. The rate of gain and the quantity of feed consumed per 100 pounds gain during the hardening period were practically normal, considering the high initial and final weights of the hogs.

B. CORN WITH TANKAGE FOLLOWING SOY BEANS

Incomplete results of hardening hogs on corn with tankage after softening on soy beans were reported in Department Bulletin 1407 (*4*). It was shown conclusively, however, that pigs beginning on soy beans at weights of from 85 to 114 pounds, inclusive, and making equal gains on the softening and hardening rations, usually do not produce firm carcasses. Further work has yielded additional data, and broader conclusions may now be stated.

The Mississippi station and the Animal Husbandry Experiment Farm fed the hogs in the experiments reported here. Four tests, extending over a period from the fall of 1921 to the spring of 1925, were conducted by each institution. The softening period in the different experiments varied from 6 to 8 weeks, while the hardening period varied from about 4 to 12 weeks. The initial weights of the 78 hogs included in the report ranged from 85 to 160 pounds, inclusive. For the purpose of more clearly presenting the results the 78 hogs were divided into two major groups according to initial weights. The weight limits of these two groups were from 85 to 114 pounds, inclusive, and from 115 to 160 pounds, inclusive, the former group containing 43 hogs and the latter 35 hogs.

SOFTNESS OF THE CARCASSES

Table 5 gives a summary of data from these two groups of hogs.

TABLE 5.—*Average weights, gains, days on feed, gradings, and refractive indexes of back and leaf fats for 78 hogs fed soy beans followed by corn and tankage*

[Initial weight of hogs on soy beans, 85 to 160 pounds, in two groups]

Number of hogs	Initial weight, average	Gain		Days on feed		Final weight	Slaughter weight	Average grade	Refractive index	
		Soy beans	Corn	Soy beans	Corn				Back fat	Leaf fat
	Pounds	*Pounds*	*Pounds*			*Pounds*	*Pounds*			
43	101.58	28.79	92.88	51.77	52.30	223.25	211.00	Medium soft	1.4603	1.4600
35	130.46	40.71	107.37	49.60	56.74	278.54	261.63	do	1.4602	1.4598

In the case of the pigs with initial weights ranging from 85 to 114 pounds the average gain on the hardening ration was 3.23 times that made on soy beans, while the heavier group gained on the hardening ration 2.64 times that made on the softening ration. The hardening periods averaged 52.30 days and 56.74 days, respectively, but in neither case were hard or even medium-hard hogs produced as an average. The fact is clearly shown that excessive gains and time on corn with tankage as a hardening ration are required to overcome the softness caused by the exclusive feeding of soy beans to hogs of the sizes indicated.

To show these results in graphic form each group of hogs was divided according to gains made on the softening ration and further divided with reference to gains made on the hardening ration. Figure 6 illustrates the results which were obtained with the hogs having initial weights of from 85 to 114 pounds. The three subgroups made average gains of 13, 36, and 54 pounds on soy beans. The subsequent hardening on the corn ration is clearly shown in each case. As with peanuts, however, the softening on soy beans evidently occurred more rapidly than the subsequent hardening on corn with nonsoftening supplement, in relation to the gains made on the two rations. Points A, B, and C represent gains of 26, 72, and 108 pounds on the hardening ration after gain of 13, 26, and 54 pounds, respectively, on soy beans. The former figure is double the latter in each instance. All three points indicate degrees of firmness which would class such hogs as soft or medium soft. This result is covered by a conclusion released by the cooperating agencies after the 1925 conference (7). The conclusion follows:

> Soy beans grazed alone or with minerals self-fed to pigs starting at weights ranging from 85 to 160 pounds and making at least a moderate rate of gain through a period of from six to eight weeks will not produce firm carcasses in the usual case, even though a subsequent gain in weight has been made by the pigs on corn with tankage double that previously made on soy beans.

Figure 7 shows the results which have been obtained with the hogs having initial weights of 115 to 160 pounds, inclusive. The average gains on soy beans made by the three subgroups were 15, 38, and 61 pounds. In each case the hardening influence of the corn ration is very clearly shown. The hardening in all three subgroups, however, occurred more slowly than the softening on soy beans, in relation to the gains made on the two rations. It will be recalled that the same

was true of the hogs fed peanuts and of the 85 to 114 pound pigs on soy beans, both already reported in this bulletin. Points A, B, and C represent gains of 30, 76, and 122 pounds on corn with tankage after gains of 15, 38, and 61 pounds, respectively, on the softening ration. In other words, the gain on the hardening ration was double that on the softening ration in each instance. Each of the three points indicates a degree of firmness classing such hogs as medium soft, all three refractive indexes falling between 1.4601 and 1.4605, inclusive. These results formed the basis of the conclusion just stated. Figure 7, however, also shows that gains on hardening feed much greater than those indicated by points A, B, and C were insufficient to produce strictly hard hogs.

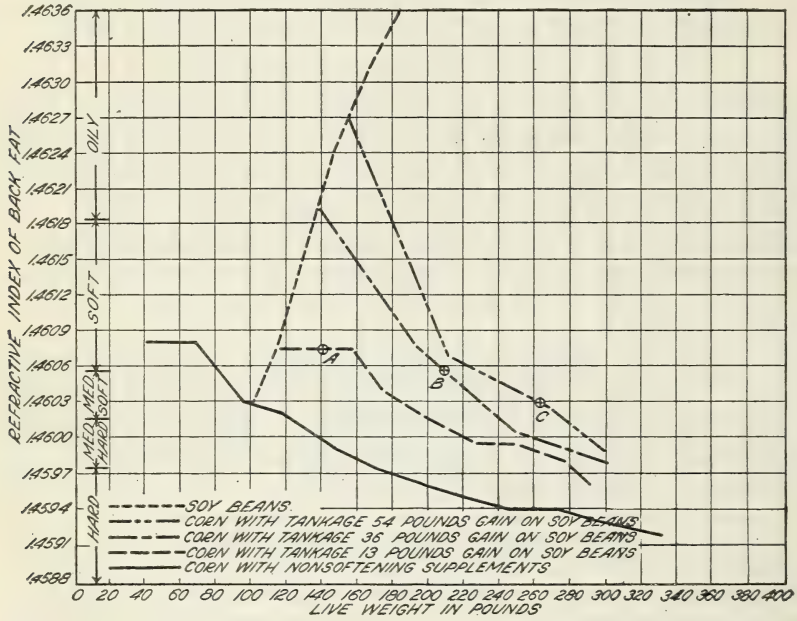

FIG. 6.—Hardening on corn with tankage following softening on soy beans. Initial weights of pigs, 85 to 114 pounds

FEEDING RESULTS WITH CORN AND TANKAGE FOLLOWING SOY BEANS

Feeding results are available from the eight experiments in which corn was fed with tankage following soy beans to pigs having average initial weights, in the different tests, of more than 84 pounds. As stated, the feeding was done at the Mississippi station and at the Animal Husbandry Experiment Farm, and covered the period from late in 1921 to early in 1925. The actual range of average initial weights in the eight experiments was from 88 to 144 pounds, inclusive. The average initial weight of the 122 hogs used was 109.61 pounds.

In the four experiments at the Mississippi station the Mammoth Yellow variety of soy beans was fed, while in the four at the Beltsville station the Virginia variety was used. In all cases the soy beans were "hogged down," beginning after the pods had begun to turn

brown. Mineral mixture [6] was self-fed to a total of 20 hogs in the 1923 and 1924 experiments at the Beltsville station, whereas the other 102 hogs received no supplement while grazing the soy beans. The results from the 20 hogs do not justify separate or comparative presentation, and they are included with the others in this summary. Mineral mixture [6] was self-fed, free choice, with corn and tankage during the hardening period of all Beltsville experiments. In the Mississippi experiments mineral mixture was not used. The grazing periods in the experiments varied from 42 to 56 days in duration, while the hardening periods ranged from 26 to 85 days owing to the successive killings. A summary of the feeding results from these experiments by periods is given in Table 6.

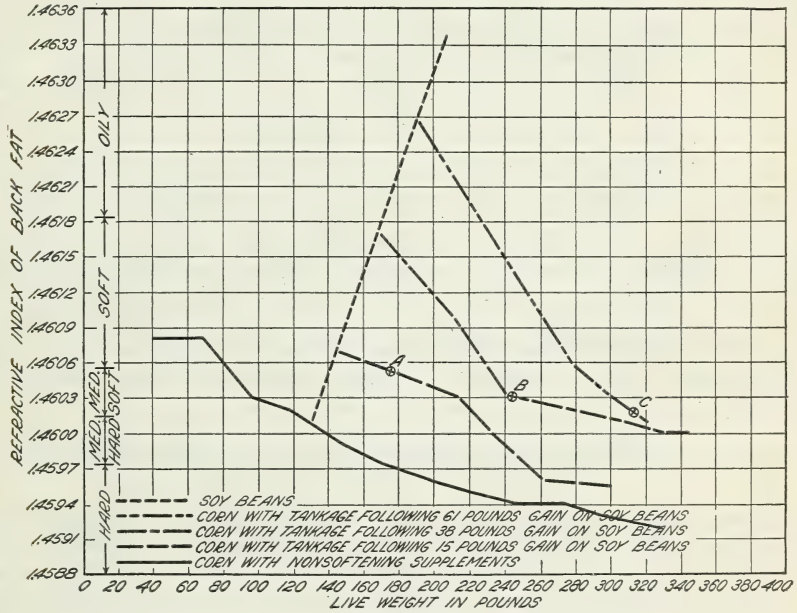

FIG. 7.—Hardening on corn with tankage following softening on soy beans. Initial weights of pigs, 115 to 160 pounds

TABLE 6.—*Results of feeding corn and tankage self-fed, free choice, in dry lot following soy beans grazed*

SOY-BEAN GRAZING PERIOD		
Number of pigs used		122
Average number of days fed		50.14
Average initial weight	pounds	109.61
Average final weight	do	140.68
Average gain	do	31.07
Average daily gain	do	.62
CORN-AND-TANKAGE FEEDING PERIOD		
Number of pigs used		98
Average number of days fed		52.61
Average initial weight	pounds	140.47
Average final weight	do	236.19
Average gain	do	95.72
Average daily gain	do	1.82
Average feed consumed per 100 pounds gain:		
Shelled corn	pounds	401.02
Tankage	do	23.40
Mineral mixture (based on results from 62 hogs)	do	6.69
Total feed	do	431.11

[6] See footnote 5.

The large number of hogs represented by Table 6 is worthy of particular notice. The difference between the numbers used in the two periods is explained by the fact that 24 hogs were slaughtered at the termination of the soy-bean grazing.

The daily gain during the first period was rather low, although, in view of the large number of hogs involved, it is probably a reliable average figure for the feeding employed, under conditions such as existed. It should be pointed out, however, that there was a wide variation in the rate of gain, from 0.17 pounds per hog per day in one Beltsville experiment to 1.21 pounds in one experiment at the Mississippi station. In fact, the gains on soy beans in the Mississippi experiments were consistently more rapid than in the Beltsville experiments. The probability of different varieties of soy beans or soy beans grown on different soils possessing different feeding values for hogs was pointed out in Department Bulletin 1407 (*4*). It is possible that the difference in feeding results in these experiments may be accounted for in this way. Further work must be done on this question. In one of the two Beltsville experiments in which mineral mixture was self-fed to one of the lots, considerably more rapid gain was made by the lot receiving minerals; in the other experiment the lot without minerals gained slightly more rapidly.

The rate of gain during the average hardening period of 52.61 days was very satisfactory. Likewise, the feed required to produce 100 pounds gain during that period shows that the hogs utilized the feed to great advantage. Study of the figures from which Table 6 was prepared shows that the 62 hogs which were fed minerals with the corn and tankage consumed 13.7 per cent less total feed (including minerals) per 100 pounds gain than the 36 others.

C. CORN WITH TANKAGE FOLLOWING SOY BEANS SUPPLEMENTED WITH A MEDIUM RATION OF SHELLED CORN

Results reported in Department Bulletin 1407 (*4*) showed the feed combination of soy beans, grazed or self-fed, with a medium (2 to 2.5 per cent)[7] ration of shelled corn to have a softening effect. The combination had a distinct, softening influence on pigs with average initial weights of 70, 100, and, also, 130 pounds, in the 12 experiments reported.

It was considered important to determine the requirements for hardening such soft hogs on corn with tankage, and the Mississippi and North Carolina stations, with the Animal Husbandry Experiment Farm, conducted the experiments furnishing the results included in this summary. Nine tests, involving 74 hogs with initial weights of 85 pounds and over, were performed during a period from late in 1921 to early in 1925. In four of these tests the hogs were fed by the Mississippi station, in one test by the North Carolina station, and in the others by the Beltsville station. Seven of the tests were continuations throughout the hardening period of experiments

[7] A 2 to 2.5 per cent ration of shelled corn is 2 to 2.5 pounds of that feed per day for each 100 pounds live weight of hogs. In these investigations recalculation of the quantity of supplementary shelled corn was made on each weighing day of the hogs. In no case did the period elapsing between weighing days exceed two weeks.

partially reported in Department Bulletin 1407 (4). They were reported in part in that publication to show the influence of soy beans with a 2 to 2.5 per cent ration of shelled corn. In the two other tests, in which the hogs were fed by the Mississippi and Beltsville stations, beginning in the fall of 1924, three killings were made from each, after 4, 8, and 12 weeks on the hardening ration. The Mammoth Yellow variety of soy beans was used in all the Mississippi station tests and in the North Carolina test, while at the Beltsville station the Virginia variety was used in all cases. The softening period in the different experiments varied from 6 to 8 weeks, while the hardening period varied from approximately 4 to 12 weeks.

To make a clear presentation of the results the 74 hogs were divided into two groups according to initial weights. The initial weights varied from 85 to 114 pounds, inclusive, in one group, and from 115 to 176 pounds in the other. The lighter-weight group contained 31 hogs and the heavier-weight group 43 hogs.

SOFTNESS OF THE CARCASSES

The essential data from the lighter-weight group of hogs are summarized in Table 7.

TABLE 7.—*Average weights, gains, days on feed, gradings, and refractive indexes of back and leaf fats for 31 hogs fed corn with tankage following soy beans supplemented with a medium ration of shelled corn*

[Initial weight of hogs on soy beans with corn, 85 to 114 pounds, inclusive]

Number of hogs	Initial weight	Gain		Days on feed		Final weight	Slaughter weight	Grading (average and distribution) [1]	Refractive index	
		Soy beans with corn	Corn with tankage	Soy beans with corn	Corn with tankage				Back fat	Leaf fat
	Pounds	*Pounds*	*Pounds*			*Pounds*	*Pounds*			
31	99.84	38.84	84.65	53.29	46.23	223.33	212.90	MS{7 S, 11 MS, 9 MH, 4 H}	1.4603	1.4598

[1] The initial letters in this column=S, soft; MS, medium soft; MH, medium hard; H, hard.

The average initial weight of the 31 hogs in this group was 99.84 pounds, or very close to the standard beginning weight of 100 pounds which was followed in connection with a majority of the experiments. Calculations show that the average daily gain on the softening ration was 0.73 pound, and on the hardening ration 1.83 pounds. The difference of 10.43 pounds between the final weight and slaughter weight was due to a shrinkage in shipping and to the hogs having received their last feed 24 hours prior to slaughter. The average total gain on the softening ration was 38.84 pounds, the variation being from 20 to 63 pounds. The subsequent gain on corn with tankage averaged 84.65 pounds, with a range of from 26 to 171 pounds. Although the gain was 2.18 times as much on the hardening as on the softening ration, the carcasses of the 31 hogs were graded

medium soft, as an average, and the refractive index of back fat was 1.4603.

To show these results in graphic form the group of hogs was divided and arranged in series according to gains made on the corn-tankage ration. Figure 8 illustrates the results. The curves for corn with nonsoftening supplements and soy beans with a medium ration of shelled corn were taken from Figure 14, Department Bulletin 1407 (*4*). The curve representing the hardening on corn with tankage following the softening on the soy-beans-corn ration shows clearly the influence of the corn-tankage ration. There was an uninterrupted increase in firmness beginning at the point at which the hardening ration was first fed. It appears, however, that the hardening progressed more rapidly until a weight of about 200 pounds was attained than afterwards. This apparent behavior has been observed in connection with other lines of feeding and it is now believed that,

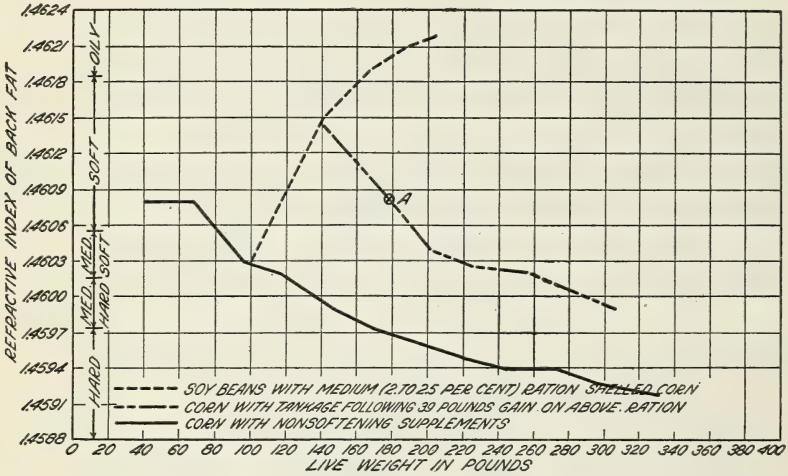

FIG. 8.—Hardening on corn with tankage after softening on soy beans with a medium (from 2 to 2.5 per cent) ration of shelled corn. Initial weights of pigs, 85 to 114 pounds

in general, it is normal for the rate of hardening to decrease in relation to the gain as the hog takes on weight and finish.

Point A represents a gain of 39 pounds on the hardening ration after a similar gain, which was the average for the 31 hogs, on the soy-beans-corn ration. Reference to the grade limits indicated on the left side of Figure 8 shows clearly that at point A the hogs were still quite soft.

The facts brought out above in Table 7, in Figure 8, and in the discussion furnished the basis for the following conclusion which was released after the 1925 conference (*7*):

Soy beans grazed with a supplementary ration of 2.5 per cent of shelled corn with or without minerals self-fed to pigs starting at weights ranging from 85 to 115 pounds and making gains of approximately 20 to 60 pounds through a period of from six to eight weeks will not produce firm carcasses in the usual case even though a subsequent gain in weight has been made by the pigs on corn with tankage equal to that previously made on the soy bean—2.5 per cent corn ration.

Strict interpretation of the data suggests that the hogs considered in the summary did not harden so rapidly as would be expected under usual conditions. This applies in particular to the hogs which gained relatively slowly on the softening ration. As a consequence of their slower rate of gain they made less total gain on the softening feed, yet a greater proportional gain on the hardening ration was required to reach any certain degree of firmness than with the other hogs. No definite reason, however, can be ascribed for the somewhat abnormal behavior. Regardless of such behavior, however, the statement above is regarded as conservative and dependable, with a margin of safety of practically 100 per cent allowed. In other words, referring again to the figures in Table 7, it is seen that the gain on corn with tankage was more than double the gain on the softening ration; yet the carcasses averaged medium soft in grading. Figure 8 also shows that a gain ratio of 1:2 (softening gain in relation to hardening gain) did not produce hard or medium-hard hogs.

RESULTS FROM HEAVIER PIGS

The average initial weight of the 43 heavier hogs as shown in Table 8 was approximately 30 pounds more than that of the 31 hogs just discussed. It is calculated from the figures for gains and days on feed that the average daily gain during the softening period was 1.39 pounds and during the hardening period 1.81 pounds. The shrinkage of 17.37 pounds from final weight to slaughter weight seems excessive, but is largely accounted for by the fact that a majority of the 43 hogs were subjected to a long shipment by express and were "empty," to a considerable extent, when weighed just prior to slaughter. The range in gains on the softening ration was from 38 pounds to 94 pounds, with an average of 67.63 pounds. The subsequent gains on the corn-tankage ration varied from 34 pounds to 162 pounds, the average gain being 94.09 pounds. Thus, with a ratio of 1 to 1.4 for the average gain on the softening as compared with that on the hardening ration a carcass grading of medium hard and refractive index of the back fat of 1.4600 were obtained.

As with the lighter pigs, the results obtained are shown graphically in Figure 9 as well as in Table 8.

TABLE 8.—*Average weights, gains, days on feed, gradings, and refractive indexes of back and leaf fats for 43 hogs fed corn with tankage following soy beans supplemented with a medium ration of shelled corn*

[Initial weights, of hogs on soy beans with corn, 115 pounds and over]

Number of hogs	Initial weight	Gain		Days on feed		Final weight	Slaughter weight	Grading (average and distribution) [1]	Refractive index	
		Soy beans with corn	Corn with tankage	Soy beans with corn	Corn with tankage				Back fat	Leaf fat
	Pounds	*Pounds*	*Pounds*			*Pounds*	*Pounds*			
43	128.35	67.63	94.09	48.51	52	290.07	272.7	MH {17 H, 18 MH, 5 MS, 3 S}	1.4600	1.4594

[1] The initial letters in this column=S, soft; MS, medium soft; MH, medium hard; H, hard.

The curves for corn with nonsoftening supplements and soy beans with a medium ration of shelled corn in Figure 9 were taken from Figure 14, in Department Bulletin 1407 (*4*). The hardening which occurred subsequently to the softening on the soy-beans-corn ration is clearly shown in the chart. A continuous and fairly steady increase in firmness is indicated by the curve representing the hardening. A decline of about 10 points in refractive index, from approximately 1.4609 to 1.4599, is shown. The latter point was reached at a weight of approximately 320 pounds. The hardening appears to have proceeded somewhat more rapidly during the early part of the period than during the latter part.

Point A in Figure 9 represents a gain on corn and tankage of 1.5 times that previously made on the soy-beans-corn ration. It falls well within the limits of the medium-hard grade, with a refractive index of about 1.4600.

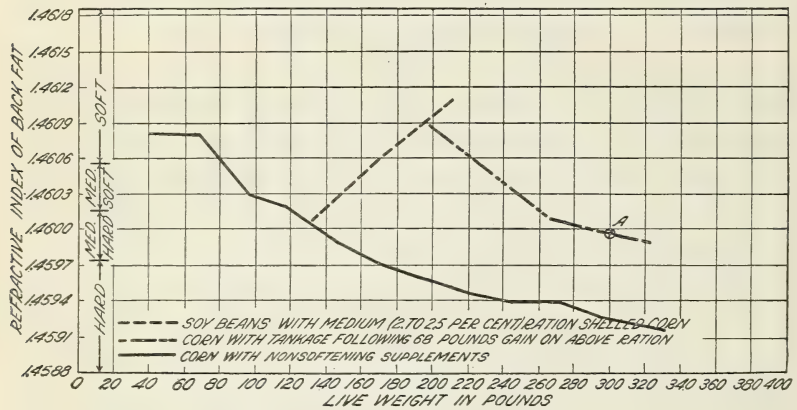

FIG. 9.—Hardening on corn with tankage after softening on soy beans with a medium (from 2 to 2.5 per cent) ration of shelled corn. Initial weights of pigs, 115 to 176 pounds

The results from the 43 hogs as brought out in Table 8, in Figure 9, and in the discussion provided the basis for another of the 1925 conclusions (*7*) released after the conference of that year. The conclusion follows:

> Soy beans grazed with a supplementary ration of 2.5 per cent of shelled corn with or without minerals self-fed to pigs starting at weights of 115 pounds and over and making gains of approximately 40 to 90 pounds through a period of from six to eight weeks will produce firm carcasses in the usual case provided a subsequent gain in weight is made on corn with tankage 1.5 times that previously made on the soy-bean–2.5 per cent corn ration.

This statement, like the preceding one, is very conservative. The data suggest, in fact, that gain on the hardening ration equal to that made on the softening ration may be depended on to produce firm hogs. This, however, is not offered as a conclusion, but to point out the approximate margin of safety allowed in the statement.

FEEDING RESULTS FROM SOY BEANS WITH MEDIUM (2 TO 2.5 PER CENT)[8] RATION OF SHELLED CORN FOLLOWED BY CORN WITH TANKAGE

Feeding results are available from the nine experiments in which corn was fed with a supplement of tankage following soy beans supplemented with a medium ration of shelled corn to pigs having average initial weights in the different tests of more than 84 pounds. These are the same experiments summarized under the preceding section on firmness of carcasses. The actual range of average initial weights in the nine experiments was from 88 pounds to 141 pounds, inclusive, while the average weight for all 134 hogs at the beginning of the experiments was 110 84 pounds.

As stated, the Mammoth Yellow variety of soy beans was used in the Mississippi and North Carolina tests, and the Virginia variety in those conducted at the Beltsville station. The beans were hogged down in all cases, the experiments beginning after the bean pods had begun to turn brown. The pigs in all lots were weighed periodically, and using these weights as bases the amounts of shelled corn to be fed per day were calculated. Weighings of the pigs and recalculations of feed were always made as frequently as every two weeks and in some cases more frequently. By this method of calculation the shelled corn fed to the hogs averaged somewhat less than 2.5 per cent of their weight. Mineral mixture[9] was self-fed during the soy-bean-grazing period to a total of 20 hogs, or to half of the animals in the 1923 and 1924 tests at Beltsville. One hundred and fourteen of the hogs had no mineral supplement with the soy beans and corn. While there is some indication that the minerals were fed with advantage in the two Beltsville experiments, the results do not seem to justify separate presentation, and are included with the others in this summary. Only in the Beltsville experiments were minerals self-fed with the corn and tankage during the finishing or hardening period.

A summary of the feeding results from the nine experiments by periods is given in Table 9.

TABLE 9.—*Results of feeding soy beans grazed supplemented with a medium (2–2.5 per cent) ration of shelled corn, followed by corn and tankage, self-fed, free choice in dry lot*

SOY-BEAN GRAZING PERIOD		
Number of pigs used		134
Average number of days fed		50.52
Average initial weight	pounds	110.84
Average final weight	do	162.34
Average gain	do	51.50
Average daily gain	do	1.02
Feed consumed per 100 pounds gain (exclusive of soy beans): Shelled corn	do	325.29
Average percentage of shelled corn (based on weight of pigs) consumed daily	do	2.43
CORN-AND-TANKAGE FEEDING PERIOD		
Number of pigs used		98
Average number of days fed		52.32
Average initial weight	pounds	159.96
Average final weight	do	252.61
Average gain	do	92.65
Average daily gain	do	1.77
Feed consumed per 100 pounds gain:		
Shelled corn	do	407.24
Tankage	do	27.67
Mineral mixture (based on results from 56 hogs)	do	7.61
Total		442.52

[8] See footnote 7.

[9] See footnote 5.

Thirty-six of the hogs were slaughtered at the close of the soy-bean-grazing period. This explains the difference between 134 and 98, the numbers of hogs fed in the two periods. The average rate of gain during the first period was only moderate, while the variation in the different lots was from 0.47 pound to 1.87 pounds, inclusive. In the two Beltsville experiments in which comparative lots were fed with and without minerals the rates of gain of the former were 1.25 pounds and 0.53 pound as compared with 0.55 and 0.47 pounds, respectively, of the latter. It is believed that the difference between 1.25 pounds and 0.55 pound in the first experiment is much greater than should be expected under average conditions. The amount of shelled corn consumed per unit of gain during the grazing period was rather high. To summarize, it is evident that the soy beans consumed by the hogs had a value, as an average, of approximately 100 pounds of grain for each 100 pounds of gain made, since 425 to 450 pounds of concentrated feed are usually required to produce that gain in hogs of the size used in these experiments.

During the finishing period on corn with tankage the 98 hogs gained rapidly. The total feed consumed per unit of gain was normal. The 56 hogs which were fed minerals with the corn and tankage consumed 17.01 per cent less total feed (including minerals) for each 100 pounds gain than the 42 others.

RESULTS WITH 25 TO 85 POUND PIGS

In view of the recognized importance of initial weight as a factor in influencing variations in firmness, additional experiments were conducted under this system of feeding, utilizing pigs having a range of initial weights from 25 to 85 pounds. Three experiments were conducted during a period from August, 1923, to January, 1926. The South Carolina station fed the hogs in all three of these tests. Complete data are available on 29 hogs.

It was the plan in these experiments to hand feed 2 pounds of shelled corn per day per 100 pounds live weight of hogs, as supplementary to the mature soy beans which were grazed. The pigs were weighed at 14-day intervals during the tests and the amount of shelled corn to feed recalculated each weighing day on the basis of these weights. The average percentages of shelled corn (based on the weights of the animals) consumed daily in the three experiments were 1.64, 1.88, and 1.85, respectively, with a general average percentage of 1.8. Haberlandt, Mammoth Yellow, and Biloxi varieties of soy beans were grazed in succession in the first experiment, Mammoth Yellow and Biloxi in the second, and Haberlandt 38 (Herman) and Mammoth Yellow in the third. The grazing period was 71 days in the first test and 56 days in each of the others. Shelled corn and tankage were self-fed, free choice, in dry lot during the finishing or hardening period of all the experiments. The hardening period was of 84 days' duration in both the first and third experiments and 81 days in the second. Mineral-mixture supplement composed of charcoal 12 parts, ground limestone 4 parts, and common salt 1 part, by weight, was self-fed throughout all tests.

Killings of representative animals were made after approximately four and eight weeks' hardening and at the close of the period.

Weights of pigs used.—The actual range of starting weights of the 29 pigs was from 24 to 62 pounds, inclusive, with an average initial weight of 37.14 pounds.

Firmness of carcasses.—The 29 hogs made gains on soy beans with supplements of from 38 to 69 pounds, inclusive, and gains on the hardening ration of from 47 to 168 pounds, inclusive. The hogs were divided into groups according to the gains made on the corn and tankage ration, as follows: Group 2, 0 to 49 pounds; Group 3, 50 to 99 pounds; Group 4, 100 to 149 pounds; Group 5, 150 pounds and over, Group 1 being an average for all 29 hogs. The weights, gains, days fed, committee gradings, and refractive indexes of back and leaf fats were averaged for each group and the results are shown in Table 10.

TABLE 10.—*Average weights, gains, feeding periods, gradings, and refractive indexes of back and leaf fats of 29 hogs fed corn with tankage following soy beans supplemented with a medium (1.8 per cent) ration of shelled corn, and by groups, according to increasing gains on the hardening ration*

Number of hogs and gain on corn and tankage	Grading (average and distribution)[1]	Initial weight	Gain on—		Days on feed		Slaughter weight	Refractive index	
			Soy beans with corn	Corn with tankage	Soy beans with corn	Corn with tankage		Back fat	Leaf fat
		Pounds	*Pounds*	*Pounds*			*Pounds*		
All hogs (29)	MS{4H, 7 MH, 11 MS, 7 S}	37.14	53.79	96.34	62.21	57.45	173.00	1.4602	1.4595
Gain, 0 to 49 pounds, on corn and tankage (2)	S (2 S)	36.50	44.00	47.50	56.00	28.00	115.50	1.4610	1.4596
Gain, 50 to 99 pounds, on corn and tankage (15)	MS{4 MH, 6 MS, 5 S}	38.33	57.20	76.73	64.00	44.27	157.47	1.4604	1.4597
Gain, 100 to 149 pounds, on corn and tankage (9)	MH{1 H, 3 MH, 5 MS}	34.00	51.78	118.67	62.67	77.11	190.55	1.4599	1.4592
Gain, 150 pounds and over, on corn and tankage (3)	H (3 H)	41.00	49.30	160.00	56.00	84.00	236.30	1.4599	1.4591

[1] The initial letters in this column=S, soft; MS, medium soft; MH, medium hard; H, hard.

The average carcass grading and refractive index of back fat for the 29 hogs were medium soft and 1.4602, respectively. In other words, neither the hard nor medium-hard degree of firmness was reached by these hogs, as an average, although a gain of 96.34 pounds on corn and tankage followed the gain of 53.79 pounds on the soy-beans-corn ration. Referring to Groups 2, 3, 4, and 5 in the table it is seen that with increasing gains on corn and tankage there was increasing firmness in the carcasses. In Group 2, where practically equal gains were made during the softening and hardening periods, the average carcass grading was soft, with a refractive index of 1.4610. Group 3 gained 76.73 pounds on corn and tankage following 57.2 pounds on the softening ration, making a gain ratio of 1:1.34. There was a distinct improvement over the preced-

ing group, the average carcass grading being medium soft, with 1.4604 as the refractive index of back fat.

In Group 4, where a gain of 118.67 pounds was made on the hardening ration after 51.78 pounds gain on the soy-beans-corn ration, the average carcass grading was medium hard. The average grading, however, was barely over the line separating the medium soft and medium-hard grades. The average refractive index of back fat fell to 1.4599. All three hogs in Group 5, which made average gains of 49.3 pounds and 160 pounds on the softening and hardening rations, respectively, were graded as hard by the committee, while their average refractive index of back fat was 1.4599.

It is apparent that a gain on corn with tankage well over 100 pounds is necessary to produce medium-hard or hard hogs under conditions such as existed in these experiments. With the gain of 118.67 pounds made by Group 4 the medium-hard degree of firmness was just reached. These results substantiate one of the conclusions released by the cooperating agencies in July, 1926 (*8*), as follows:

> Soy beans grazed with a supplementary ration of 1.5 to 2.5 per cent of shelled corn and with minerals self-fed to pigs starting at weights ranging from 25 to 85 pounds and making gains of approximately 40 to 75 pounds through a period of from 8 to 10 weeks produce, in the usual case, carcasses of a satisfactory degree of firmness when a subsequent gain in weight of 125 pounds or more has been made by the pigs on corn with tankage.

FEEDING RESULTS WITH 25 TO 85 POUND PIGS FED CORN WITH TANKAGE FOLLOWING SOY BEANS GRAZED SUPPLEMENTED BY A MEDIUM RATION OF SHELLED CORN

Feeding results are available from the three experiments presented in the preceding section on firmness and in which the pigs were fed by the South Carolina station. The pigs were fed as described in the preceding section and were turned on the soy beans as the beans reached the dough stage and the leaves began to turn brown.

Fifteen pigs were used in each of the three tests. The average initial weights of the pigs were 36.27, 59.69, and 35.8 pounds in the 1923–24, 1924–25, and 1925–26 experiments, respectively, while the general average beginning weight was 43.92 pounds. The ages of the animals ranged from 10 to 20 weeks when the experiments began.

A summary of the feeding results from both the soy-bean grazing periods and finishing periods of the three tests is given in Table 11.

TABLE 11.—*Results of feeding corn with tankage following soy beans grazed supplemented by a medium (2 per cent) ration of shelled corn hand fed*

	SOY-BEAN GRAZING PERIOD
Number of pigs used	45
Average number of days fed	61.00
Average initial weight, pounds	43.92
Average final weight, do	105.58
Average gain, do	61.66
Average daily gain, do	1.01
Feed consumed per 100 pounds gain:	
Shelled corn, do	131.25
Mineral mixture, do	11.89
Total feed, do	143.14
Average percentage of shelled corn (based on weight of pigs) consumed daily	1.80

TABLE 11.—*Results of feeding corn with tankage following soy beans grazed supplemented by a medium (2 per cent) ration of shelled corn hand fed*—Con.

CORN-AND-TANKAGE FEEDING PERIOD

Number of pigs used		45
Average number of days fed		54.00
Average initial weight	pounds	105.58
Average final weight	do	198.66
Average gain	do	93.08
Average daily gain	do	1.72
Feed consumed per 100 pounds gain:		
Shelled corn	do	406.85
Tankage	do	38.65
Mineral mixture [1]	do	4.20
Total feed	do	449.70

[1] Mineral mixture composed of: Charcoal, 12 parts; ground limestone, 4 parts; common salt, 1 part.

The average daily gain of 1.01 pounds during the soy-bean grazing period must be regarded as very satisfactory, expecially when consideration is given to the small size of the pigs at the beginning of the tests. The feed consumed per 100 pounds gain, in addition to the soy beans grazed, commands particular attention. As an average 143.14 pounds of feed, exclusive of soy beans, were consumed by the pigs in making 100 pounds of gain. Since 400 or more pounds of grain or concentrated feed are usually required to produce 100 pounds of gain in dry lot, it is obvious that the bean crops grazed in these experiments had an average value equal to about 250 pounds of grain for each 100 pounds of gain made. These results indicate that this is a very satisfactory method of feeding growing pigs and of utilizing soy beans as a hog feed.

During the finishing period these pigs also made a very satisfactory rate of gain. The feed consumed per 100 pounds gain during this period was approximately normal for pigs of their size.

D. SOY BEANS WITH CORN IN DEFINITE PROPORTION

With the marked increase in the production and feeding of soy beans in the United States conditions sometimes arise under which the farmer considers it desirable to feed them as the protein supplement to corn in dry lot or on pasture. The softening influence of the soy beans can not be disregarded, however, and the feeder is confronted with the question as to the proportion in which they can be fed without producing soft hogs. This question was deemed of sufficient importance to receive full consideration in these investigations.

The Indiana station and the Animal Husbandry Experiment Farm conducted the tests reported below. The work was begun in 1924 and phases of it are still incomplete. The plan for the first series of experiments provided for study of the influence of mixtures of ground corn and ground soy beans in proportions of 12:1, 9:1, 6:1, and 3:1 when fed in dry lot for fattening purposes. The Indiana station has completed four experiments and the Animal Husbandry Experiment Farm one experiment in this series. In the former cases the Manchu variety of soy beans was used and in the latter case the Virginia variety. In all five experiments the mixture of ground corn and ground soy beans in each lot was self-fed, free choice, with mineral mixture and pressed block salt. The mineral mixture was composed of wood ashes, 10 pounds; 16 per cent acid phosphate, 10 pounds; and common salt, 1 pound.

Results considered as conclusive have been obtained from the lots fed the 3:1 combination of corn and soy beans. The results from this combination only are reported in this bulletin. Further work is to be done with the 12:1, 9:1, and 6:1 mixtures before the results are published.

COMPOSITION OF THE FEEDS

Table 12 shows the composition of the soy beans used in the different experiments, together with the average composition of the beans used. For comparison is given the average composition of soy beans as reported by Henry and Morrison (*5*). The average analysis of No. 2 dent corn as reported by them is shown also. It is believed that this represents satisfactorily the average of the corn fed in the five experiments.

TABLE 12.—*Composition of soy beans and corn*

Feed	Water	Ash	Crude protein	Fiber	Nitrogen-free extract	Fat
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Soy-bean seed (first Indiana experiment)	6.2	6.4	38.7	4.5	27.4	16.8
Soy-bean seed (second Indiana experiment)	5.8	5.5	32.4	5.4	32.1	18.8
Soy-bean seed (third Indiana experiment)	5.8	5.5	32.4	5.4	32.1	18.8
Soy-bean seed (fourth Indiana experiment)	5.8	5.5	32.4	5.4	32.1	18.8
Soy-bean seed (Beltsville experiment)	9.9	4.4	37.8	5.2	25.2	17.5
Average	6.7	5.5	34.7	5.2	29.8	18.1
Average, soy-bean seed (*5*)	9.9	5.3	36.5	4.3	26.5	17.5
Average, No. 2 dent corn (*5*)	14.8	1.4	9.6	1.9	67.6	4.8

WEIGHTS OF PIGS USED

Complete data are available on 46 hogs fed the 3:1 mixture of the two feeds. The range of average initial weights in the five experiments was from 64 pounds to 132 pounds, while that of the individual initial weights was from 49 to 146 pounds. The average beginning weight for the 46 pigs was 106.13 pounds.

SOFTNESS OF CARCASSES

A total of 12 representative or check pigs were slaughtered and studied at the beginning of four of the experiments considered in this group. Owing to an insufficient number of animals available it was not practicable to slaughter checks in the other case. The 12 pigs had an average slaughter weight of 102.92 pounds and their average refractive index of back fat was 1.4604. It is believed that the condition of these 12 pigs, as indicated by this refractive-index value, was representative of the initial condition of the pigs which were fed experimentally.

Check or control lots were self-fed a mixture of ground corn 12 parts and tankage 1 part with the mineral mixture mentioned above for comparison with the soy-bean lots in all five experiments. To show in general the comparative results of feeding the corn-soy-bean and corn-tankage mixtures Table 13 is given.

TABLE 13.—*Average weights, gains, feeding periods, gradings, and refractive indexes of back and leaf fats of 46 hogs self-fed a mixture of ground corn 3 parts and ground soy beans 1 part, and of 44 hogs self-fed a mixture of ground corn 12 parts and tankage 1 part, both rations including mineral supplements*

Ration	Number of hogs	Grading (average and distribution)[1]	Initial weight	Gain	Days fed	Daily gain	Weight at slaughter	Refractive index	
								Back fat	Leaf fat
			Pounds	*Pounds*		*Pounds*	*Pounds*		
Corn, soy beans, and minerals	46	S{34S, 9MS, 3MH}	106.13	110.89	82.20	1.35	203.22	1.4614	1.4604
Corn, tankage, and minerals	44	H{1S, 3MS, 4MH, 36H}	107.52	134.95	76.89	1.76	227.75	1.4594	1.4587

[1] The initial letters in this column=S, soft; MS, medium soft; MH, medium hard; H, hard.

While the average initial weights of the hogs fed the corn-soy-bean and corn-tankage rations were 106.13 and 107.52 pounds, respectively, the ranges of individual starting weights were from 49 to 146 pounds and from 53 to 155 pounds. With average gains of 110.89 and 134.95 pounds the individual gains varied from 55 to 164 pounds on the corn-soy-bean ration and from 63 to 201 pounds on the corn-tankage ration.

Table 13 shows that all except 3 of the 46 hogs fed soy beans with corn were graded soft or medium soft by the committee, the 3 being classed as medium hard. The refractive indexes of back fat of these 3 hogs, however, were 1.4611, 1.4609, and 1.4608. With an average refractive index of 1.4614 for the 46 hogs there was a variation of from 1.4603 to 1.4626. On the other hand, all except 4 of the 44 hogs fed tankage with corn were graded hard or medium hard, 3 of the 4 being classed as medium soft and the other hog as soft. The refractive indexes of back fat of the 3 medium-soft hogs were 1.4601, 1.4599, and 1.4599, and that of the soft hog was 1.4599. The variation in refractive indexes of back fat of the 44 hogs was from 1.4589 to 1.4601, the average being 1.4594.

These facts in reference to the influence on firmness of the corn-soy-bean (3:1) combination of feeds formed the basis for one of the conclusions which were released by the cooperating agencies in July, 1926 (*8*), as follows:

> Soy beans fed as a supplement to corn in dry lot in the ratio of 1 pound of soy beans to 3 pounds of shelled corn to pigs ranging up to 130 pounds in starting weights will not produce firm carcasses in the usual case when the hogs are slaughtered after a gain of approximately 100 pounds or more has been made on the corn-soy-bean ration.

It is of interest that there was a difference, as indicated above, of 10 points in refractive index between the 12 check pigs and the 46 hogs finished on the corn-soy-bean ration. The rise of from 1.4604 to 1.4614 shows that a distinct softening influence was exerted by the 3:1 combination of feeds. On the other hand, the fall of from 1.4604 to 1.4594 with the 44 hogs fed the corn-tankage (12:1) ration shows plainly that a hardening occurred. In other words, starting at the same point (1.4604) there was a rise of 10 points in the one case

and a fall of 10 points in the other, resulting in the wide difference of 20 points at the termination of the experiment.

The average composition of the mixtures of corn and soy beans fed in these experiments is worthy of consideration. This is calculated from the composition figures given in Table 12 and is shown below in Table 14.

TABLE 14.—*Calculated average composition of mixtures of ground corn 3 parts and ground soy beans 1 part fed in 5 experiments at the Indiana station and the Animal Husbandry Experiment Farm*

Water	Ash	Crude protein	Fiber	Nitrogen-free extract	Fat
Per cent 12.8	*Per cent* 2.4	*Per cent* 15.9	*Per cent* 2.7	*Per cent* 58.1	*Per cent* 8.1

The fat content and the nature of the fat of any feed or feed combination are recognized as the principal factors controlling softness or firmness in the hog. Attention is directed especially, therefore, to the average fat content of these mixtures as shown in the table. About 44 per cent of the fat in the mixture was corn fat and 56 per cent soy-bean fat. Both fats are softening in nature. While 8.1 per cent of softening fat in a ration does not seem high, yet its influence under the conditions which existed in these experiments has been clearly shown.

FEEDING RESULTS WITH MIXTURE OF GROUND CORN, THREE PARTS, AND GROUND SOY BEANS, ONE PART

Complete feeding results are available from the five experiments included in the preceding summary on the degree of firmness found in the carcasses. As stated, the hogs in four experiments were fed by the Indiana station and those in the other experiment by the department station at Beltsville, Md. In all cases the mixture of ground corn, three parts, and ground soy beans, one part, by weight, was self-fed, free choice, with the mineral mixture and pressed block salt in dry lot. The Manchu variety of soy beans was used in the Indiana tests and the Virginia variety at Beltsville. The five experiments covered a period of about 20 months, from November, 1924, to June, 1926.

The variation in average initial weights of the pigs used in the several experiments was from 64 to 132 pounds, with an average starting weight of 105.50 pounds for all 48 pigs fed. Table 15 summarizes the feeding results of these experiments.

TABLE 15.—*Results of feeding ground corn, three parts, and ground soy beans, one part, mixed, self-fed, free choice, with mineral mixture and pressed block salt, in dry lot*

[Five experiments, four at the Indiana station and one at Beltsville]

Item	Indiana				Beltsville	Average
Experiment number	1	2	3	4	5	
Number of pigs used	10	10	8	10	10	9.6
Average number of days fed	80	105	70	62	98	83
Average initial weight—pounds	122.50	64.30	131.63	118.90	95.40	105.50
Average final weight—do	231.50	191.90	233.50	220.80	211.60	217.21
Average gain—do	109	127.60	101.87	101.90	116.20	111.71
Average daily gain—do	1.36	1.22	1.46	1.64	1.19	1.34
Average feed consumed per 100 pounds gain:						
Ground corn—pounds	366.61	318.02	355.34	354.86	317.56	340.47
Ground soy beans—do	122.20	105.96	118.40	118.25	105.85	113.47
Mineral mixture [1]—do	4.50	8.13	1.78	2.85	5.59	4.87
Total—do	493.31	432.11	475.52	475.96	429	458.81

[1] Includes pressed block salt.

The average initial weights in experiments 2 and 5 were lower than in the others. While the average daily gains were also lower, the feed utilization was considerably better in these experiments than in the others. More economical use of feed is commonly expected, of course, with younger hogs than with older ones, and the results obtained here probably can be accounted for in this way.

The general average of 458.81 pounds of feed consumed per 100 pounds gain is a figure which must be regarded as very satisfactory. It indicates clearly that ground soy beans fed under conditions such as prevailed in these experiments constitute a valuable protein supplement to corn for use in fattening well-grown pigs.

E. RICE BRAN WITH TANKAGE

Rice bran is one of the several by-products of rice milling which are used extensively in certain sections of the country as hog feeds. Results obtained at the Arkansas (*1*), Texas (*9*), and California (*6*) stations have shown that rice bran when fed as the basal feed produces soft carcasses. In the present investigations experiments were conducted to determine the degree of softness which develops on rice bran as compared to other softening feeds.

NATURE OF THE FEED

The average composition of the rice bran used in the experiments and, for comparison, that of rice polish, are given in Table 16.

TABLE 16.—*Composition of rice bran and rice polish* [1]

Feed	Water	Ash	Crude protein	Fiber	Nitrogen-free extract	Fat
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Rice bran	6.8	11.7	12.9	13.6	39.3	13.7
Rice polish	10.3	6.3	11.9	1.9	57.5	12.1

[1] From Bureau of Chemistry, United States Department of Agriculture.

The composition of the rice bran here shown is very similar to the averages given in tables of feeding standards. Rice bran as compared to rice polish has a decidedly higher ash and fiber content and usually a slightly higher protein and fat content. Rice oil becomes rancid very readily, and when this occurs it makes the feeds somewhat distasteful to animals. In addition, rice bran when it contains excessive amounts of rice hulls is not a desirable hog feed. The admixture of rice hulls is usually indicated by the high fiber content. Excellent feeding results have been obtained in many instances by the use of good-quality rice bran just as was the case with rice polish. It has been observed, however, in the present investigations, and is amply substantiated by previous tests at the experiment stations, that the results on rice bran as shown by the gains and general thriftiness of the hogs are usually inferior to those on rice polish. Both feeds require a protein supplement for best results.

Variations in the oil content of different consignments of the same feed probably cause wider differences in the softness of the hogs than does the average difference between rice bran and rice polish.

THE EXPERIMENTS

Results from a total of 32 hogs fed rice bran as the basal feed have been summarized. In the four experiments presented, rice bran and tankage were self-fed, free choice. In one test in which the hogs were fed for 112 days by the Iberia Livestock Experiment Farm the hogs had access to a mineral mixture and received a daily allowance of 5 pounds of skim milk per hog. In another test of 56 days' duration at the same station the same method of feeding was followed except that the allowance of skim milk was reduced to 3.14 pounds. The Arkansas station fed hogs for 56 days in dry lot, supplementing the rice bran and tankage with a mineral mixture. At the Mississippi station the feeding period was 56 days and the hogs grazed on rye pasture. No mineral mixture was fed. The average initial weight of the 32 hogs was 77.25 pounds. The actual range of weights was from 43 pounds to 97 pounds, inclusive.

SOFTNESS OF THE CARCASSES

The softening effect of rice bran is shown in Table 17. Data on the four experiments are given, with the general averages for all the hogs. The wide range in the firmness of check pigs killed at the beginning of three of the experiments was largely attributable to differences in the rations fed previous to the experimental feeding period. The pigs in both Iberia farm lots received brewers' rice and skim milk as the principal components of their preexperiment rations. As indicated by the results on check pigs from the 1925 lot, this resulted in the formation of firm body fat at a stage of growth when pigs raised on the more common ration of corn and tankage have soft fat. The results given in the table strongly suggest that the firmness of the fat before the feeding of rice bran affected the degree of softness developed on this feed. Thus, with a range from hard to soft in the condition of the pigs at the start of the experiments, there resulted at the close of the experimental period a comparable range

from moderately soft to extremely soft. In all cases definite softening was produced by the feeding of rice bran.

TABLE 17.—*Average weights, gains, days fed, gradings, and refractive index of fats on 32 hogs fed rice bran and tankage*

Item	Mississippi, 1924	Arkansas, 1925	Iberia, 1925	Iberia, 1924	General average and summary
Number of hogs	9	6	7	10	32
Initial weight—pounds	70.4	82.8	74.1	82.2	77.25
Check pigs:					
Average grading [1]	S	S	H		
Refractive index (back fat)	1.4612	1.4599	1.4589		
Fat content of rice bran—per cent	14	17.2	13.2	10.4	13.7
Fiber content of rice bran—do	11.2	16.2	11	16	13.6
Gain:					
Minimum—pounds	15	9	48	95	[2] 9
Maximum—do	65	43	71	116	[3] 116
Average—do	43	25.7	61	107	63.69
Number of days fed	56	56	56	112	73.50
Average daily gain—pounds	.77	.46	1.09	.96	.87
Slaughter weight—do	101.3	98	123.3	165.6	125.72
Grading: [1]					
Average	S	S	S	S	S
Distribution	9S	6S	1O, 5S, 1MS	1O, 5S, 4MS	2O, 25S, 5MS
Refractive index at 40° C.:					
Back fat	1.4617	1.4612	1.4607	1.4603	1.4610
Leaf fat	1.4609	1.4607	1.4603	1.4599	1.4605

[1] The initial letters = O, oily; S, soft; MS, medium soft; H, hard.
[2] Actual minimum.
[3] Actual maximum.

Another factor which probably contributed to the spread in the degree of softness of the various lots is illustrated by the two Iberia farm lots. The second lot was on experiment twice as long and gained nearly twice as much as the first lot. The grades and refractive-index values indicate that the second lot averaged the firmer of the two. It has been noted (*4, p. 47, 60*) that rice polish with tankage and peanut meal in combination with corn (1 to 2 mixture) cause the development of a maximum softness which is followed by a gradual hardening as the hogs approach maturity. Since rice bran is so nearly like rice polish in composition, the behavior just outlined is probably true also of the rice bran, but without much question would show up more definitely were the hogs in the other lots more comparable. As the results stand, the Mississippi station lot shows the maximum softness, with a gain of 43 pounds. The wide differences in softness at the start of the experimental feeding periods has probably accentuated the rise and fall in degree of softness associated with the gain. With the Iberia farm lots as a basis, it appears reasonably certain that a rise and later decline in softness does occur with increase in gain.

The average on the 32 hogs fed rice bran given in Table 17 are thought to be representative of results likely to be obtained under average conditions. The degree of softness at the start of the feeding period will influence the softness attained as will also the gain. The refractive index of 1.4610 on the back fat confirms the committee grading of soft. The refractive index is one point higher than obtained on 69 hogs fed rice polish (*4, p. 45*).

The conclusion has therefore been drawn (1) that "Rice bran and tankage self-fed free choice on rye pasture or in dry lot and

with or without a supplement of 5 pounds or less of skim milk per animal daily to pigs starting at weights under 100 pounds and making gains up to 100 pounds through a feeding period of from 8 to 16 weeks produce soft carcasses."

FEEDING RESULTS FROM RICE BRAN WITH TANKAGE

Feeding results are available from six experiments in which rice bran was fed with tankage and minerals with and without additional supplements. In 2 tests the hogs were fed by the Arkansas station, in 1 by the Mississippi station, and in 3 by the Iberia Livestock Experiment Farm, La. The work covered the period from 1923 to 1926, inclusive. All of the 133 hogs used in the experiments were self-fed on rice bran, tankage, and mineral mixture by the free-choice method. In the Mississippi station experiment the hogs grazed on green-rye pasture. No record of mineral consumption was kept in that test. In one Iberia farm experiment the hogs grazed on green-oat pasture and received a daily allowance of 3.14 pounds of skim milk per animal. The other 4 lots, 2 at the Iberia farm and 2 at the Arkansas station, were fed in dry lot. As in the Iberia farm experiment referred to, however, skim milk was fed as an additional supplement in the latter two tests at that station. In one case 5 pounds and in the other 3.14 pounds was the average daily allowance.

The variation in average initial weights of the pigs in the several experiments was from 71.26 pounds to 94.18 pounds, inclusive. The average initial weight of the 133 pigs was 84.14 pounds.

The feeding results from the six experiments are summarized in Table 18.

TABLE 18.—*Results of feeding rice bran with tankage to hogs in dry lot and on pasture*

Item	Self-fed, free choice, on green oat or rye pasture		Self-fed, free choice, in dry lot	
	Mississippi	Iberia	Arkansas	Iberia
Number of experiments	1	1	2	2
Number of pigs	24	16	44	49
Average initial weight—pounds	71.26	80.50	76.45	91.70
Average number of days fed	52.33	56	56	67.43
Average final weight—pounds	116.25	141	102.78	156.73
Average gain—do	44.99	60.50	26.33	65.03
Average daily gain—do	.86	1.08	.47	.96
Feed consumed per 100 pounds gain:				
Rice bran—do	384.63	420.97	603.94	520.96
Tankage—do	24.91	14.25	55.70	21.81
Mineral mixture—do	[1] 10	8.57	2.41	13.87
Skim milk—do		290.50		390.96
Total feed—do	[1] 419.54	734.29	662.05	947.60
Total on grain basis (estimating 6 pounds skim milk as equal to 1 pound grain)—pounds	[1] 419.54	492.21	662.05	621.80

[1] Estimated.

The hogs are shown in four groups. The differences in the feeding of these groups have already been indicated. Each group on pasture gained at a more rapid rate than the corresponding group in dry lot.

Of the two lots on pasture the one receiving milk gained more rapidly, and the same was true of those fed in dry lot. With the exception of the Iberia farm group fed on pasture the rates of gain were under 1 pound a day. The mineral mixture consumed per 100 pounds gain in the Mississippi experiment was estimated at 10 pounds. It is obvious that the feed consumption per unit of gain in the Mississippi station experiment, as well as in the Iberia farm test on pasture, was considerably less than in the two in dry lot. Approximately from 25 to 30 per cent less grain feed per unit of gain was consumed by the 40 hogs on pasture than by the 93 hogs in dry lot. In all cases, however, the feed consumption was high in relation to the gain made by the hogs. This fact considered in connection with the generally low rates of gain suggests that the value of rice bran as a fattening feed for hogs is below the standard of first-class feeds.

F. RICE BRAN WITH TANKAGE FOLLOWED BY CORN WITH TANKAGE

The problem of hardening hogs fed on rice bran is comparable in most respects to that on rice polish. The experiments throughout the work with rice bran have paralleled those with rice polish and the results with respect to firmness are very similar. The initial weights of the hogs on which results are presented range from 50 to 114 pounds. The eight-week feeding period on rice bran was followed by eight weeks on corn or brewers' rice. As shown in the feeding outline of the experiments, a number of supplements were used with these feeds.

HARDENING RESULTS FROM CORN WITH SUPPLEMENTS

A total of 44 hogs were fed in 5 experiments on rations of rice bran, tankage, and minerals for 8 weeks, followed by corn, tankage, and minerals for 8 weeks, with the exception of 3 hogs in the Mississippi experiment which were fed in 5 and 11 week periods, respectively. Further feeding details for the several experiments are as follows:

Arkansas, 1925, self-fed, free choice, dry lot.
Arkansas, 1926, self-fed, free choice, dry lot.
Iberia, 1925, self-fed, free choice, on oat pasture and given a daily supplemental feed of 3.14 pounds of skim milk per animal.
Iberia, 1926, self-fed, free choice, dry lot, and given a daily supplemental feed of 3.14 pounds of skim milk per animal.
Mississippi, 1924, self-fed, free choice, on rye pasture.

The data on weights, gains, and firmness are give in Table 19. As in the experiments on the effects of rice bran shown in Table 17, the hogs in the Iberia farm experiments, which received brewers' rice before the experimental period, had a rather firm fat at the start of the softening period. The average gains on rice bran were higher than in other lots, and those on corn were of only average amount, yet the hogs were among the firmest of all the experiments. The gains on rice bran were usually lower than on rice polish. Further discussion on the feeding value of rice bran is given on page 34. The difference in the firmness of the hogs in the two Arkansas station experiments may be attributed to a considerable degree to the difference in oil content of the rice bran. In the 1925 experiment the oil

content was 17.2 per cent, while in 1926 it was 11.7 per cent. In the first case the carcasses graded an average of medium soft and in the second medium hard. In comparison of the two experiments it should be noted, however, that the gain on hardening feed in the 1926 experiment was larger, but at the same time the hogs were softer at the beginning of the experiment.

TABLE 19.—*Average weights, gains, gradings, and refractive indexes of fat of 44 hogs fed rice bran with supplements followed by corn with supplements*

Item	Arkansas, 1925	Iberia, 1926	Arkansas, 1926	Iberia, 1925	Mississippi, 1924	General average and summary
Number of hogs	9	13	8	6	8	44
Initial weight, pounds	84.1	84.9	74.8	78.5	65.5	78.50
Check pigs:						
Grading [1]	MS	MS	S	H	S	MS
Refractive index (back fat)	1.4600	1.4592	1.4612	1.4589	1.4609	1.4600
Fat percentage of rice bran	17.2	13.7	11.7	13.2	14.0	14.0
Gain, rice-bran period:						
Minimum, pounds	19	43	13	46	12	[2] 12
Maximum, do	41	59	40	72	73	[3] 73
Average, do	31.0	51.3	25.1	61.2	43.3	42.27
Gain, corn period:						
Minimum, pounds	72	72	88	90	87	[2] 72
Maximum, do	123	119	145	103	136	[3] 145
Average, do	99.8	104.5	119.0	95.0	118.1	107.34
Ratio of gains:						
Softening to hardening, 1 to	3.23	2.02	4.76	1.56	2.60	2.54
Average daily gain—						
Rice-bran period, pounds	0.55	0.93	0.45	1.09	0.90	0.75
Corn period, do	1.78	1.88	2.12	1.70	1.85	1.92
Slaughter weight, do	204.2	226.5	208.0	220.2	214.9	215.00
Grading: [1]						
Average	MS	MS	MH	MH	H	MH
Distribution	1 S, 4 MS 3 MH, 1 H	8 MS, 4 MH 1 H	1 S, 2 MS 4 MH, 1 H	1 MS, 2 MH 3 H	8 H	2 S, 15 MS 13 MH, 14 H
Refractive index at 40° C.:						
Back fat	1.4600	1.4596	1.4595	1.4595	1.4597	1.4596
Leaf fat	1.4592	1.4592	1.4590	1.4591	1.4591	1.4591

[1] The initial letters = S, soft; MS, medium soft; MH, medium hard; H, hard.
[2] Actual minimum.
[3] Actual maximum.

It is apparent that increasing ratios between gains in the softening and hardening periods do not always indicate increasing firmness. It usually does in cases of equal gains on softening feeds, but with greater gain on rice bran the decrease in softness following the early rise causes a shifting in the gain ratio necessary to get a certain degree of firmness.

The distribution of grades in certain of the lots indicates the uncertainty of obtaining satisfactorily firm hogs with the feeding plan used in this work. The average figures on the 44 hogs show that a gain, on corn, of 2.5 times that on rice bran produced an average grading of medium hard. However, the general distribution of grades between medium soft, medium hard, and hard, together with the distribution among the individual experiments, indicates the generally unsatisfactory results obtained. A total of 31 out of the 44 hogs gained 35 pounds or over on rice bran, or an average of 51 pounds. The gain on corn was 107 pounds, which is somewhat more than twice that on rice bran. The gradings show 19 hard and medium-hard and

12 medium-soft and soft carcasses, a distribution almost identical with the results on the entire number. The results indicate that a more extended feeding period on corn will be necessary to get more nearly uniform production of hard and medium-hard carcasses, when pigs with initial weights of approximately 80 pounds are fed eight weeks on rice bran.

FEEDING RESULTS FROM RICE BRAN WITH TANKAGE FOLLOWED BY CORN WITH TANKAGE

Feeding results from the hardening period on corn with tankage and other supplements have been summarized for the five experiments just discussed under the subject of hardening results. The feeding results from the rice-bran period of these same experiments were given in Table 18.

The results as shown in Table 20 cover a total of 51 hogs. This includes a number of animals not reported in the summary of hardening results because their initial weights were outside the range of 50 to 114 pounds. The gains during the 56-day feeding period were all very satisfactory, and in most cases in marked contrast with those made during the preceding period on the rice-bran ration. Likewise, the feed consumption per 100 pounds of gain showed very satisfactory utilization. There was no consistent difference between the pasture and dry-lot experiments in the gains or feed utilization. These results indicate that the rice bran had no lasting ill effects on the rate of growth and the feed requirements, especially in view of the great improvement noted in the dry-lot group, when changed to the corn ration.

TABLE 20.—*Results from feeding corn with tankage following rice bran with tankage, in dry lot and on pasture*

Item	Self-fed, free choice, on green-oat or rye pasture		Self-fed, free choice, in dry lot	
	Mississippi	Iberia	Arkansas	Iberia
Number of experiments	1	1	2	1
Number of pigs	5	8	19	19
Average initial weight—pounds	124.40	140.63	102.63	148.37
Average final weight—do	229.00	234.50	211.27	253.21
Average gain—do	104.60	93.87	108.64	104.84
Average number days fed—days	56.00	56.00	56.00	56.00
Average daily gain—pounds	1.87	1.68	1.94	1.88
Feed consumed per 100 pounds gain:				
Shelled corn—do	430.21	379.76	382.48	451.51
Tankage—do	10.13	5.33	20.27	9.44
Mineral mixture—do	[1] 5.00	7.06	.56	5.62
Skim milk—do	----------	187.48	----------	167.67
Total feed—do	445.34	579.63	403.31	634.24
Total on grain basis (6 pounds skim milk per 1 pound grain) pounds	445.34	423.40	403.31	494.52

[1] Estimated.

G. RICE POLISH WITH NONSOFTENING SUPPLEMENTS, FOLLOWED BY CORN AND BREWERS' RICE WITH NONSOFTENING SUPPLEMENTS

Results from the feeding of rice polish with tankage and additional supplements, which were reported in Department Bulletin 1407 (*4*) showed that this ration produced soft carcasses when pigs were

begun on experiment at weights between 35 and 125 pounds and made gains of 30 pounds or more in from 8 to 15 weeks. This section deals with the hardening of pigs which have become soft on rice polish. Experiments have been conducted with two basal, hardening feeds, namely, corn and brewers' rice.

The pigs used in these experiments averaged about 70 pounds at the start; those included in this summary ranged in weight from 50 to 114 pounds. They were fed eight weeks on the rice-polish ration and then for an additional eight weeks on the hardening ration. By this system, pigs of a marketable weight somewhat above 200 pounds were usually produced.

HARDENING RESULTS FROM CORN WITH PROTEIN SUPPLEMENTS

The results of the feeding systems in which corn with protein and mineral supplements has followed a softening feed, such as peanuts or soy beans, have shown that the hogs became firmer as the gain on the corn ration increased. It has been extremely difficult, however, to obtain carcasses with a good degree of firmness in any reasonable length of time. Since rice polish is not so softening as peanuts or soy beans, the difficulties in hardening pigs fed rice polish with the subsequent feeding of corn should be materially lessened.

All the experiments discussed in this section were confined to the plan of using equal feeding periods of eight weeks each on softening (rice polish) and hardening (corn) feeds. The hogs in these experiments were fed by the Iberia Livestock Experiment Farm, and the Arkansas, the Mississippi, and the Coastal Plain stations.

The basal softening ration was composed of rice polish, tankage, and minerals and the basal hardening ration of corn, tankage, and minerals. The rations were self-fed, free choice. Further details of the feeding plans follow.

Arkansas, 1925, both periods dry lot for 56 days each.

Arkansas, 1926, both periods dry lot for 56 days each.

Coastal Plain, 1925, both periods dry lot for 56 days each; fish meal used in place of tankage.

Iberia, 1924, both periods on oat pasture for 56 days each.

Iberia, 1926, both periods for 56 days each on oat pasture; additional daily supplement of 3.14 pounds of skim milk per animal.

Mississippi, 1924, both periods on rye pasture for 56 days, with exception of one pig on softening feed 35 days and hardening feed 77 days..

Table 21 gives the results relative to the growth and firmness of the carcasses of the hogs from the six experiments included in this section. The range of initial weights was limited to 50 to 114 pounds, inclusive. In certain lots this necessitated the omission of one or more hogs with initial weights outside this range. The lots are arranged in the table by grades from soft to hard and within grades according to refractive-index averages on back fat. The total number of hogs was 75, the general averages of which are included in the table.

TABLE 21.—*Average weights, gains, gradings, and refractive indexes of fats of 75 hogs fed rice polish and supplements followed by corn and supplements*

Item	Coastal Plain, 1925	Arkansas, 1925	Iberia, 1926	Arkansas, 1926
Number of hogs	28	8	20	8
Initial weight, pounds	69.5	81.4	68.8	73.9
Check pigs:				
Grading [1]	MS	MS	MS	S
Refractive index of back fat	1.4603	1.4600	1.4592	1.4612
Fat content of rice polish, per cent	15.8	12.6	----------	13.6
Gain:				
Rice-polish period—				
Minimum, pounds	33	17	40	19
Maximum, do	78	85	63	51
Average, do	55.6	51.5	55.8	31.9
Corn period—				
Minimum, do	45	61	65	82
Maximum, do	118	119	115	126
Average, do	86.9	94.3	88.5	107.4
Ratio of gains: Rice polish to corn, 1 to	1.55	1.83	1.57	3.34
Average daily gain:				
Rice-polish period, pounds	1.00	0.93	1.00	0.57
Corn period, do	1.55	1.68	1.57	1.91
Slaughter weight, do	201.0	211.9	196.5	203.8
Grading [1]				
Average	S	MS	MS	MS
Distribution	27 S, 1 MS	2 S, 3 MS 3 MH	1 S, 12 MS 6 MH, 1 H	1 S, 6 MS 1 H
Refractive index at 40° C.:				
Back fat	1.4602	1.4601	1.4598	1.4596
Leaf fat	1.4593	1.4595	1.4591	1.4592

Item	Mississippi, 1924	Iberia, 1924	General average and summary
Number of hogs	6	5	75
Initial weight, pounds	70.3	75.8	71.45
Check pigs:			
Grading [1]	S	MS	MS
Refractive index of back fat	1.4609	1.4601	1.4603
Fat content of rice polish, per cent	14.0	12.4	----------
Gain:			
Rice-polish period—			
Minimum, pounds	15	56	[2] 15
Maximum, do	86	75	[3] 86
Average, do	48.0	65.6	51.87
Corn period—			
Minimum, do	68	90	[2] 45
Maximum, do	148	108	[3] 148
Average, do	109.3	95.6	92.70
Ratio of gains: Rice polish to corn, 1 to	2.27	1.45	1.79
Average daily gain:			
Rice-polish period, pounds	0.86	1.18	0.93
Corn period, do	1.95	1.93	1.65
Slaughter weight, do	221.0	230.2	204.80
Grading: [1]			
Average	H	H	MS
Distribution	2 MH, 4 H	5 H	31 S, 22 MS 11 MH, 11 H
Refractive index at 40° C.:			
Back fat	1.4598	1.4597	1.4599
Leaf fat	1.4595	1.4592	1.4592

[1] The initial letters=S, soft; MS, medium soft; MH, medium hard; H, hard.
[2] Actual minimum.
[3] Actual maximum.

The grading and refractive index of back fat of the check pigs which were killed as representative of each lot of hogs at the beginning of the experimental period show some noteworthy variations. The refractive index, which in this case may be more indicative of the condition of the fat than the grading, shows extremes of 1.4592 and 1.4612, or a range of from hard to very soft. This difference was caused by the use of different rations previous to the experimen-

tal feeding. In the case of the Iberia farm lot, the basal feed was brewers' rice. Such variations in initial firmness as here shown are considered as contributing factors to the divergent final results between the various lots.

The wide range of minimum and maximum gains within certain lots probably also contributed to the wideness of the distribution of grades. This is particularly noticeable in the Arkansas station experiment of 1925. The one experiment (Iberia, 1924) in which all hogs were graded the same shows a relatively narrow range in gains. It was stated in Department Bulletin 1407 (*4*) that after passing a certain weight or degree of finish there is a tendency for hogs fed rice polish to acquire gradually a lower degree of softness. The maximum softness for hogs begun at approximately 70 pounds is reached with a gain of about 40 pounds. It therefore appears that at the close of the rice-polish period the Arkansas station lot of 1926 was softer than the Iberia, 1924, lot which had begun to harden at the time the feed was changed. This fact, together with the initial firmness, materially aided the development of firmness in the Iberia hogs, even though the gain ratio (1:1.45) was relatively narrow. The rice polish used in the Coastal Plain station experiment had a fat content of 15.8 per cent as compared with values ranging from 12.4 to 14 per cent in the other experiments. This high fat content probably developed a softer carcass during the softening period than in the Arkansas, 1925, and Iberia, 1926, lots even though the gains were comparable. The average gain on hardening feed was only 1.55 times that on softening feed, so as a result the Coastal Plain lot was the softest of all lots at slaughter.

Considering that factors of initial firmness, gains, and gain ratios are generally in line with the usual grade averages and refractive-index values, it appears that the gradings on the Mississippi, 1924, and Iberia, 1924, lots were somewhat firmer than justified. These two lots were graded at the same time, and it is entirely possible that some unknown factor was responsible for this seemingly abnormal grading.

The general average on the total of 75 hogs shows that the average gain during the rice-polish period was 51.87 pounds and during the corn period was 92.70 pounds, which is a ratio of 1:1.79. The periods were of approximately equal length, namely, eight weeks. The refractive index average on the back fat was 1.4599, which is within the medium-soft grade limits for hogs fed rice polish. The grading shows that 53 out of 75 were graded medium soft or soft. The variations between lots were such as largely to compensate each other in the averaging of results on all hogs. One factor which possibly should not be overlooked in the application of these results to practical feeding practice is the range in fat content of rice polish. The average fat content of this feed, as given by the Bureau of Chemistry, is 9.7 per cent as compared to 9.1 per cent by Henry and Morrison (*5*). These figures are decidedly lower than for any of the rice polish used in the present investigations. When rice polish of low oil content is used it is probable that less softening will develop.

These results have been summarized in the following conclusion (*7*):

Rice polish and tankage self-fed free choice on oat or rye pasture or in dry lot to pigs starting at weights under 100 pounds and making gains of 35 pounds or more through a period of from five to eight weeks will not produce firm carcasses in the usual case even though a subsequent gain in weight has been made by the pigs on corn with tankage equal to that previously made on the rice polish ration.

After the release of the above-quoted statement additional experiments were completed. With the availability of the additional results and for the purpose of a more accurate summarizing statement of the results just presented it is believed that the initial-weight limits should be specified as 50 and 114 pounds and the feeding period as approximately eight weeks.

HARDENING RESULTS FROM BREWERS' RICE WITH PROTEIN SUPPLEMENTS

As described in Department Bulletin 1407 (*4*) brewers' rice is another of the by-products of rice milling, but unlike rice polish and rice bran it is extremely low in fat. It is an excellent hog feed and has been shown to produce much firmer fat than that produced by corn. It is at once apparent that it should be a very suitable hardening feed for use subsequently to a softening feed.

Experiments on the use of brewers' rice following the feeding of rice polish have paralleled those on corn just described. In all experiments tankage and minerals were fed with rice polish during the softening period and with brewers' rice during the hardening period. These feeds were self-fed, free choice. Further details of the feeding plans of the several experiments follow:

Arkansas, 1925, both periods in dry lot for 56 days each.
Arkansas, 1926, both periods in dry lot for 56 days each.
Iberia, 1923, both periods on oat pasture for 56 days each; additional daily supplement of 3.14 pounds of skim milk per animal.
Iberia, 1924, same as Iberia, 1923.
Iberia, 1926, both periods in dry lot for 56 days each; additional daily supplement of 3.14 pounds of skim milk per animal.

The results of these experiments are given in Table 22. In many respects variations in initial firmness and in gains are comparable to those discussed in connection with Table 21. The fat content of the rice polish used in four of the lots fell within the range of from 12.4 to 14 per cent. There was an extremely wide range in the firmness of the hogs at the start of the softening period. The Iberia farm pigs in 1923 and 1926 received brewers' rice as the basal feed prior to the experiment, and consequently the check pigs show a very low refractive index. In the 1923 experiment data on 10 hogs killed at the close of the rice-polish period showed an average grade of medium soft and a refractive index of 1.4604. This indicates that less softening developed in these hogs than usually results under more average conditions. Besides the greater initial firmness, the high gain (81 pounds) on rice polish had carried these hogs well past the stage of maximum softness and so made possible the development of a higher degree of firmness after eight weeks on brewers' rice as compared to the other lots.

TABLE 22.—*Average weights, gains, gradings, and refractive indexes of fats of 46 hogs fed rice polish and supplements followed by brewers' rice and supplements*

Item	Arkansas, 1925	Arkansas, 1926	Mississippi, 1924	Iberia, 1924
Number of hogs	7	6	4	5
Initial weights, pounds	83.9	78.7	60.0	73.8
Check pigs:				
Grading [1]	MS	S	S	MS
Refractive index (back fat)	1.4600	1.4612	1.4609	1.4601
Fat content of rice polish, per cent	12.6	13.6	14.0	12.4
Gain:				
Rice-polish period—				
Minimum, pounds	26	18	51	51
Maximum, do	60	55	84	78
Average, do	45.1	37.5	62.0	65.2
Brewers' rice period—				
Minimum, do	62	117	118	100
Maximum, do	121	178	145	140
Average, do	91.4	143.8	128.8	129.0
Ratio of gains: Rice polish to brewers' rice, 1 to	2.02	3.80	2.08	2.00
Average daily gain:				
Rice-polish period, pounds	0.80	0.68	1.11	1.16
Brewers' rice period, do	1.63	2.57	2.30	2.30
Slaughter weight, do	206.3	243.2	243.3	264.0
Grading: [1]				
Average	MS	MH	H	H
Distribution	4 S, 2 MH 1 H	1 MS, 2 MH 3 H	4 H	5 H
Refractive index at 40° C.:				
Back fat	1.4598	1.4591	1.4594	1.4592
Leaf fat	1.4595	1.4588	1.4590	1.4588

Item	Iberia, 1926	Iberia, 1923	General average and summary
Number of hogs	18	6	46
Initial weights, pounds	66.7	77.5	72.48
Check pigs:			
Grading [1]	MS	H	MS
Refractive index (back fat)	1.4592	1.4585	1.4600
Fat content of rice polish, per cent			
Gain:			
Rice-polish period—			
Minimum, pounds	29	72	[2] 18.0
Maximum, do	73	91	[3] 91.0
Average, do	58.7	85.8	58.36
Brewers' rice period—			
Minimum, do	50	107	[2] 50
Maximum, do	130	147	[3] 178
Average, do	101.9	129.8	114.72
Ratio of gains: Rice polish to brewers' rice, 1 to	1.85	1.53	1.97
Average daily gain:			
Rice-polish period, do	0.98	1.45	1.04
Brewers' rice period, do	1.82	2.32	2.05
Slaughter weight, do	212.7	290.7	234.11
Grading: [1]			
Average	H	H	H
Distribution	1 MH, 17 H	6 H	4 S, 2 MS 4 MH, 36 H
Refractive index at 40° C.:			
Back fat	1.4590	1.4586	1.4591
Leaf fat	1.4585	1.4582	1.4587

[1] The initial letters=S, soft; MS, medium soft; MH, medium hard; H, hard.
[2] Actual minimum.
[3] Actual maximum.

The softest lot was that of the Arkansas station in 1925. As in the lot for the following year, the gains on rice polish were relatively low, yet were sufficient to develop the maximum of softness. Although the gain on the hardening ration was twice that on the softening ration, the average grade of this lot was medium soft. Increasing total gains (softening plus hardening) and slaughter weights are associated with increasing firmness, with the possible exception of the Iberia, 1926, lot.

The average results on the entire group of 46 hogs are convincing in showing that hard hogs can be produced by the feeding of brewers' rice subsequent to rice polish. The average refractive index of the back fat was 1.4591 compared to 1.4594 for hogs of similar weight grown and fattened on corn and tankage. The average firmness of the carcasses was approximately the same for the two methods of feeding. The difference of three points in the refractive index is explained by the fact that hogs which have been fed rice polish or rice bran show lower refractive-index grade limits than corn-fed hogs. (Table 1.) The results show that gains amounting to approximately a pound a day during the softening period of 56 days and about 2 pounds per day during the hardening period of equal length produced 87 per cent hard or medium-hard hogs weighing close to 240 pounds.

FEEDING RESULTS FROM RICE POLISH WITH TANKAGE, FOLLOWED BY CORN AND BREWERS' RICE WITH TANKAGE

Feeding results (Table 23) are available from eight experiments in which rice polish was fed with tankage and minerals, with and without additional supplements, and followed by corn and brewers' rice with similar supplements. In 2 experiments the hogs were fed by the Arkansas station, in 1 by the Coastal Plain station, in 4 by the Iberia Farm, and in 1 by the Mississippi station. One hundred and seventy-six pigs were used and all were self-fed rice polish, tankage, and mineral mixture, by the free-choice method, during the first period. In four experiments the pigs were fed on green-oat or rye pasture and in the other four in dry lot. Skim milk was also fed in one experiment on pasture and in one in dry lot.

TABLE 23.—*Results of feeding rice polish with supplements, followed by corn and brewers' rice with supplements, on pasture and in dry lot*

Item	Self-fed, free choice, on green-oat or rye pasture		Self-fed, free choice, in dry lot	
	Iberia, 2 experiments and Mississippi, 1 experiment	Iberia, 1 experiment	Arkansas, 2 experiments, and Coastal Plain, 1 experiment	Iberia, 1 experiment
Basal feed used during softening period	Rice polish	Rice polish	Rice polish	Rice polish
Number of pigs used	60	11	65	40
Average initial weight—pounds	75.08	70.91	72.24	68.23
Average final weight—do	136.40	148.91	117.37	124.45
Average gain weight—do	61.32	78	45.13	56.22
Average number of days fed	54.53	56	56	56
Average daily gain—pounds	1.12	1.39	.81	1
Average feed consumed per 100 pounds gain:				
Rice polish—pounds	349.30	284.03	380.66	336.68
Tankage—do	28.68	27.97	43.58	12.81
Skim milk—do		225.52		305.82
Mineral mixture—do	9.46	5.13	3.52	8.45
Total feed consumed per 100 pounds gain	387.44	542.65	427.76	663.76
Total feed, grain basis (6 pounds milk=1 pound grain)	387.44	354.72	427.76	408.91

TABLE 23.—*Results of feeding rice polish with supplements, followed by corn and brewers' rice with supplements, on pasture and in dry lot*—Continued

Item	Self-fed, free choice, on green-oat or rye pasture			Self-fed, free choice, in dry lot			
	Iberia, 2 experiments, and Mississippi, 1 experiment		Iberia, 1 experiment	Arkansas, 2 experiments, and Coastal Plain, 1 experiment		Iberia, 1 experiment	
Basal feed used during finishing period	Corn	Brewers' rice	Brewers' rice	Corn	Brewers' rice	Corn	Brewers' rice
Number of pigs used	11	15	5	46	17	20	19
Average initial weight—pounds	141.09	146.87	149	120.37	110.24	124.55	124.05
Average final weight—do	242.27	276	282.60	212.39	220.36	213.05	224.37
Average gain weight—do	101.18	129.13	133.60	92.02	110.12	88.50	100.32
Average number of days fed	56	56	56	56	56	56	55.3
Average daily gain—pounds	1.81	2.31	2.39	1.64	1.97	1.58	1.82
Average feed consumed per 100 pounds gain:							
Corn—pounds	417.97			398.27		336.78	
Brewers' rice—do		385.59	380.84		345.09		329.90
Tankage—do	18.33	9.81	2.84	32.43	11.61	10	8.03
Mineral mixture—do	[1] 6.35	[2] 4.61	2.25	3.81	.80	5.14	4.88
Skim milk—do			131.73			222.94	193.97
Total feed	442.65	400.01	517.66	434.51	357.50	574.86	536.78
Total feed on grain basis (6 pounds milk=1 pound grain)	442.65	400.01	407.88	434.51	357.50	389.08	375.14

[1] Based on results from 6 hogs. [2] Based on results from 10 hogs.

Twenty-six of the 60 hogs fed rice polish, tankage, and minerals on oat or rye pasture were finished in two lots of 11 and 15 hogs on corn and brewers' rice, respectively, each with tankage, minerals, and oat or rye pasture. Five of the 11 hogs fed skim milk with the rice-polish ration on pasture during the first period were finished on the same feed combination, except that brewers' rice replaced the rice polish.

In the dry-lot feeding, rice polish, tankage, and minerals were self-fed to 105 hogs during the first period of four experiments. Sixty-six of these were finished in three lots on corn with supplements, whereas 36 were finished on brewers' rice with supplements. The range of average initial weights in the several experiments was from 68 to 83 pounds. The average initial weight of the 176 pigs was 72.83 pounds.

In the summarized feeding results shown in Table 23, there are several consistent differences between groups worthy of mention. During the softening period on rice polish the lots receiving skim milk in addition to tankage gained at a more rapid rate. The lots on pasture required less feed, exclusive of pasture, than the corresponding lots in dry lot. Undoubtedly the most interesting result from the hardening period is the high feeding value of brewers' rice. The average daily gains of the lots on brewers' rice were decidedly higher than the corresponding ones on corn. In two cases the average gains were above 2 pounds a day.

SUMMARY

Undesirable characteristics are found in the products of soft hogs. These characteristics are attributable to a lack of firmness in the fat.

The products from typical soft hogs are inconvenient to handle and unattractive to many people. The producer marketing hogs suspected of being soft usually must accept a lower price than if the hogs are thought to be firm, or sell subject to grading after chilling.

Until recent years the problem was regarded as of importance only in peanut-producing sections of the country. Later developments, however, including a remarkable expansion in the use of soy beans in hog production, have enlarged it to one of nation-wide scope.

Cooperative investigations were inaugurated by a number of the State stations and the Bureau of Animal Industry on July 1, 1919. The work has been continued as a cooperative enterprise from the beginning without interruption. The experiments were conducted in accordance with a program formulated each year by the conference of cooperators. With few exceptions the hogs used in the work were slaughtered and graded for firmness at the Animal Husbandry Experiment Farm at Beltsville, Md. Back fat and leaf fat samples were taken from each hog carcass for laboratory examination. The refractive index was adopted as the standard laboratory measure of firmness of the fats.

The annual conference of cooperators also studied results in detail, made deductions from these results, recommended publications, and approved or disapproved material prepared for publication.

The soft-pork problem, fundamentally, is a fat problem. When the fat of feeds is stored by the hog there is no essential change in its character with respect to firmness or softness. The fat of most of the common feeds is soft and in some cases fluid at ordinary temperatures. There is enough fat in some feeds to account for all of that stored. In such cases the body fat closely resembles the feed fat. With feeds low in fat and high in carbohydrates there is little similarity between the fat consumed by the hog and that found in the body when the animal has been fed at least to a moderate weight and degree of finish. This is attributable to the admixture of a firm fat synthesized from the carbohydrates. When fed in excess of the body's needs for growth and maintenance, protein may enter also into fat formation and there is no evidence to indicate that it produces soft fat.

In brief, the character of fat stored seems to a great extent to be governed, primarily, by the amount and character of fat and, secondarily, by the amounts of carbohydrates and protein, particularly the former, in the feed consumed in relation to the rate of fat deposition.

When a hog grows and fattens normally the rate of fat deposition gradually increases. Thus, while a low-fat feed may contain practically fat enough to fulfill the fat-storage requirements of the younger hog it probably will not contain enough for the older hog fattening at a more rapid rate. The other nutrients, particularly the carbohydrates, must enter into fat formation to an increasing extent under these conditions. This results in the hog becoming firmer as it acquires weight and finish.

The reader is referred to Department Bulletin 1407 (*4*) for a more detailed explanation and discussion of the soft-pork problem and of the methods used in this cooperative study.

Following are conclusions covering the experimental work reported in this bulletin (numbers are for convenient reference):

(1) Peanuts grazed or self-fed in dry lot with or without minerals to pigs starting at weights ranging from 85 to 114 pounds and making gains of approximately 40 pounds or more on that feed through a period of approximately eight weeks will not produce firm carcasses at the usual market weight of 200 to 225 pounds attained by subsequent feeding of corn with tankage after the peanuts. Results have shown, in fact, that gain on corn with tankage up to approximately 120 pounds, this maximum being produced during a feeding period of approximately 16 weeks' duration, following gains of 40 or more pounds on peanuts, usually will not produce hard or medium-hard hogs. As the gain on peanuts increases, the subsequent gain on corn with tankage necessary to produce a certain degree of firmness likewise increases.

In comparing the results from the pigs having initial weights of from 115 to 142 pounds with those from the lighter-weight pigs (referred to above) it is apparent that it is fully as difficult to produce firm hogs from the former as from the latter. There is an indication, in fact, that the hardening progresses more slowly with the heavier pigs, the gains on peanuts having been equal. The results strongly suggest that if a practical plan of producing firm hogs under this system of feeding is to be developed it must make use of pigs weighing less than 85 pounds at the beginning of the peanut feeding.

(2) Soy beans grazed alone or with minerals self-fed to pigs starting at weights ranging from 85 to 160 pounds and making at least a moderate rate of gain through a period of from six to eight weeks will not produce firm carcasses in the usual case even though a subsequent gain in weight has been made by the pigs on corn with tankage double that previously made on soy beans.

(3) Soy beans grazed with a supplementary ration of 2.5 per cent of shelled corn with or without minerals self-fed to pigs starting at weights ranging from 85 to 114 pounds and making gains of approximately 20 to 60 pounds through a period of from six to eight weeks will not produce firm carcasses in the usual case even though a subsequent gain in weight has been made by the pigs on corn with tankage equal to that previously made on the soy beans—2.5 per cent corn ration.

(4) Soy beans grazed with a supplementary ration of 2.5 per cent of shelled corn with or without minerals self-fed to pigs starting at weights of 115 pounds and over and making gains of approximately 40 to 90 pounds through a period of from six to eight weeks will produce firm carcasses in the usual case provided a subsequent gain in weight is made on corn with tankage 1.5 times that previously made on the soy-bean—2.5 per cent corn ration.

(5) Soy beans grazed with a supplementary ration of 1.5 to 2.5 per cent of shelled corn and with minerals self-fed to pigs starting at weights ranging from 25 to 85 pounds and making gains of approximately 40 to 75 pounds through a period of from 8 to 10 weeks

produce, in the usual case, carcasses of a satisfactory degree of firmness when a subsequent gain in weight of 125 pounds or more has been made by the pigs on corn with tankage.

(6) Soy beans fed as a supplement to corn in dry lot in the ratio of 1 pound of soy beans to 3 pounds of shelled corn to pigs ranging up to 130 pounds in starting weights will not produce firm carcasses in the usual case when the hogs are slaughtered after a gain of approximately 100 pounds or more has been made on the corn-soybean ration.

(7) Rice bran and tankage self-fed free choice on rye pasture or in dry lot and with or without a supplement of 5 pounds or less of skim milk per animal daily to pigs starting at weights under 100 pounds and making gains up to 100 pounds through a feeding period of from 8 to 16 weeks produce soft carcasses.

(8) Rice bran with tankage followed by corn with tankage fed to pigs with initial weights of from 50 to 114 pounds through equal feeding periods of eight weeks each has not produced uniformly firm carcasses. The wide distribution in the gradings of the carcasses, even though the average gain of the hogs on hardening feed was over twice that on softening feed, is attributed to a number of factors. Among these factors were previous feeding, fat content of the rice bran, rate of gain, and relative gains on softening and hardening feeds.

(9) The hardening effects of corn and of brewers' rice fed subsequently to rice polish were determined on pigs with initial weights ranging from 50 to 114 pounds. In the case of the first-named feed it has been concluded that rice polish and tankage self-fed, free choice, on oat or rye pasture or in dry lot to pigs starting at weights of 50 to 114 pounds and making gains of 35 pounds or more through a period of approximately eight weeks do not produce firm carcasses in the usual case, even though a subsequent gain in weight has been made by the pigs on corn with tankage equal to that made on the rice-polish ration. In fact, the general average on 75 hogs shows that a gain on the corn ration of 1.79 times that on the rice-polish ration resulted in an average grading of medium soft.

On the other hand, brewers' rice fed in place of corn, other conditions being equal, has produced firm carcasses when the gain on the brewers' rice ration was twice that on rice polish.

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